A Mixed Methods Study into the Measurement of the Effects of Monochromatic Optical Pattern on Perceived Female Form

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ABSTRACT

This research aimed to establish the current state of knowledge regarding the manipulation of human perception of the female form and how this perception has been measured or quantified; to develop a method of measuring perceived differences in size of a monochromatic optical printed image/object and to investigate the influence of surface printed pattern on the human perception of the female form.

The research followed a mixed methods approach using quantitative, qualitative and tacit methods which together helped to determine the best method for measuring differences in observers' perception.

Initial testing followed a scientific route using observers in a controlled environment looking at 2D samples of different sized squares. The results of these tests proved that paired comparison was the best way of testing observers' perception. An innovative way of displaying designs on dresses using video projection and CAD was then developed. An iterative process of survey design was used, where different monochromatic optical patterned dresses were presented to a large number of observers, targeted via electronic means and social networking in order to reach a wide demographic. The observers were asked to gauge which of the two dresses presented was bigger. The results of one survey were used to inform the design of the next.

The thesis is presented as a traditional argument supported by a digital sketchbook which outlines the design process. Outcomes relating to the way in which observers observe specific placement of optical monochromatic patterns on dresses and monochromatic combinations are discussed and potential 'rules' for optical monochromatic pattern placement relating to size perception by observers were explored.

DEDICATION

You pulled out all the stops and you saw me through it!

The best doctor I know

My Mum

x

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Chapter 1 – Introduction

1.1 Context

Throughout history, cultural and religious morals have dictated how fashionable people should look and dress. This has changed over time and people have often been judged on their appearance and how they are dressed. How people look and how people would like to look depends on the culture in which they live and the time in which they are living. There are many historical precedences that suggest that when we don't fit the 'normal' body image we strive to change it. This has led to a desire to adapt one's body image to the prevailing ideal. Where we live is also a factor in how we look and what is perceived as desirable and 'normal'. The cross-cultural research carried out by Furnham and Baguma (1993) discussed the influence of geographical location on the perception of attractive or desired body shapes. Their research demonstrated that major cultural differences occur in ratings of extreme figures. For example, Ugandan participants rated very heavy female and very thin male figures as more attractive than did British participants.

Over the centuries in most cultures, bodies have been manipulated, physically and with external decoration. Cultural trends often result in concepts of beauty, which lead to the desire to change some aspect of physical appearance. Global evidence exists of painted faces and bodies and the use of tattoos to personalise and mark. This practice has been evident for centuries to differing degrees. Body piercing, clothing and accessories are some methods used to conform to fashions and cultural acceptance. The internal need to change and improve, manipulate and distort appearance appears to be a subconscious desire either to fit in or to appear different. This can also be attributed to cultural practices (Adams, 2003).

The way we see ourselves and think others perceive us is a prominent and regular feature in media, news magazines and general conversation. There is increasing evidence of interest in the perfect body (Kagawa et al, 2006) (Adams, 2003). The perfect body is a concept relative to historical and cultural norms. Recent research shows we do not have an accurate view of our bodies

(Gleeson & Frith, 2006). An individual will have an unconscious body image. We base this on perception of our own bodies compared to how we perceive others' bodies. It is believed that if we were not so influenced by cultural pressures we would have a more accurate view of our bodies. Current research shows that there is a concentration on the perceived and ideal body image rather than actual body shape (Gleeson & Frith, 2006) (Cusumano, 1997).

Against this backdrop, the initial inspiration for this research was drawn from work carried out by a group of students led by Dr Lisa Macintyre at Heriot Watt University into women's bottoms in 2005 (Hawes, 2005). The work looked at measuring changes in perceived shape and size generated by changing the cut of the garment worn. The method which students used for their study in 2005 was adopted for initial testing in this research and is documented in full in Chapter 5. However, a change of direction and a consequent need to change the method of obtaining observers perceptions is also detailed in Chapter 5.

A second reason for engaging in this research was a personal interest in the increasing media attention to the female form's size, shape and appearance. In recent times the phrase 'Does my bum look big in this?' has become commonplace in both the media and research (Thompson, 2008). Arabella Weir was the first to popularise the phrase for her character, "Insecure Woman", in The Fast Show (BBC, 1996- 2000) and then 18 months later published a book (Weir, 1997) by the same name, which remained on the best sellers list for months. Five years after Weir first started regularly writing and performing the character "Insecure Woman" an article appeared in The Independent newspaper describing the creative process behind a Barclays bank advert (Inside Story: Tim Delaney's master class in writing great ads, 2007) starring Anthony Hopkins in which he said "Does my bum look big in this?" The creator of the advert, Tim Delaney, suggested that this advert also launched the catchphrase into "the national lexicon".

1.2 Body modification through surgery

Body modification through surgery commonly known as cosmetic surgery has seen a steady increase since the late 70s, early 80s. Figures show that there has been a 12.2% increase in surgical procedure from 2006 to 2007 in the UK (BAAPS, 2008). The majority of cosmetic surgery is carried out on women (91%). The number of males having cosmetic surgery has increased by 17.5% from 2006 to 2007. Liposuction, having been one of the most popular procedures in recent years, has been superseded by facial and anti-aging procedures. Liposuction is still on the increase with a rise of 15% from 2006 however face/neck lifts were up 36% in 2007 on the previous year (BAAPS, 2008) (Jameson, 2007). This information provides evidence that women and men are not only becoming more self conscious about how they look but are also increasingly prepared to undertake drastic measures to achieve a fashionable body shape. Current plastic surgery trends are comparable to ancient practices performed to create cultural body fashions.

1.2.1 *Cultural body fashions*

One example of differing cultural body preferences is foot binding. This was practised in China for nearly a thousand years, and began by binding the feet of young girls to restrict growth and cause foot deformity. The bound feet were often prone to infection, paralysis, and atrophy. Elderly Chinese women who experienced the practice now experience disability as a result. The binding's purpose was to construct the ‘ideal’ foot of beauty, the "lotus foot", which was a 3 inch long foot (Ko, 2005).

Feet have not been the only parts of the body to be artificially altered in the name of beauty. The act of restricting or shaping starting with young bones was more common in ancient times. In parts of Africa and South America the practice of head moulding and restricting the skull was accomplished with the use of binding and strapping boards to permanently alter the shape of the skull by putting pressure on it over time. When babies are young, the skull is soft and malleable. Many anthropologists believe this type of body modification to be amongst the first practised by humans, and is seen in historical records

around the world. The practice continues today in parts of Africa and South America (Nichter et al, 1986) (Tubbs, Salter & Oakes, 2006).

One of the most common and cross-cultural forms of body modification is tattooing. Tattooing is a form of applied pattern on the body similar to printing on textile. Tattooing has probably existed for as long as humans have roamed the earth, and there is evidence of ancient tattooing within a very wide variety of cultures throughout history (Rush, 2005). An example of culturally specific tattooing which has become somewhat mainstream is the tattooing art of the Buddhist monks at the Wat Bang Phra Temple in Thailand. The monks at this temple perform ritualized daily tattooing of anyone who requests it, using a sharp needle which pushes ink into a person's flesh.

1.2.2 *The use of surgery versus clothing for beauty*

The increased media interest in appearance can be set in above historical context. There is a rich history of body modification for the purposes of beauty. This could be an indication of an inherent need amongst the human race to distort the natural appearance and shape of the human body. This leads to the need for humans to always strive for a look that is believed to be attractive or beautiful to self and to others. Delong (1998) reports that, while in more extreme cases this is achieved via means of body modification surgery (described above), a more common approach is clothing, and this study will focus on this.

1.2.3 *Manipulating the female form through clothing*

Clothing silhouettes have changed dramatically over the past century and have dictated the shape to which women, and in some cases men, are expected to conform. Until the early part of the 20th century, there tended to exist a body style of the times, achieved through clothing, whereas now people have various styles and fashions they wish to achieve.

A recent radio programme discussed the concept of a ‘lady’ (BBC, 2007). Interestingly, the discussion centred on the need to dress like a “lady”. The

concept of “lady” was, therefore, bound up with the idea of dress. It was pointed out that in times gone by ladies were almost architecturally underpinned and that to have the body of a lady required much work behind the scenes. This was all achieved through under garments and clever positioning of boning and fabrics. The body shape of a corseted lady was controlled by physically changing the structure of one’s waist, breasts and hips. Corseting or the act of modifying a woman's waist with the help of different devices achieved popularity from the 14th-20th centuries. Other forms of shaping the female form included the bustle which increased the size of the bottom which in turn gave the illusion of a smaller waist in combination with the corset, and the hoop was worn under ones skirt to make the skirt wider.

In the 1920s dresses became less structured and elaborate. Controlling women’s natural body shape became more important than creating the false body images achieved by shaping the garments worn. Modern fashions do not employ the same amount of architectural underpinning that fashion from the beginning of the last century dictated. The kind of extreme underpinning that has been seen in the past 250 years is now seldom used routinely for the control of ‘trouble areas’ such as stomach, midriff, thighs and bottoms to create what is desired in the west, a slimmer body. Since the demise of the corseted body around the 1950s different techniques have been used in apparel to create a false body shape or to deceive the viewer’s eye. In recent years the use of spanx, slimming pants and bottom enhancing pants are becoming more popular as people strive for an arguably unrealistic body ideal (BBC, 2007).

1.3 Psychological studies of factors affecting the way we see ourselves

Much of the current research into perception of the female form, body size and shape is focussed on quantifying self perception (Benson & Tovee, 1999). A common factor in the research on self perception has been that women typically over estimate their size. In their study of 159 females Thompson & Spana (2006) found that the sample overestimated the size of their waist, hips and thighs by 21%. Davies & Furnham (1986) found that British female adolescents felt that they were overweight and expressed a desire to lose weight and change their body image. This common trend could be attributed to

a particular ‘ideal’ female form, this shape being something different from what we naturally are (Saltzberg, 1995). There is a constant need for perfection and a desire to fit the stereo type of what is ‘beautiful’ or ‘good’ (Rodin, 1993) (Saltzberg, 1995) (Norton, Olds, Olive, & Dank, 1996). Older research suggests that traditionally the measuring of body image has been evaluated by using techniques such as interviews, questionnaires and projective tests (Glucksman, 1969).

Specialist equipment or techniques have been used to help quantify self perception. There is a shift in techniques from using equipment to relying on one’s own perception through questionnaires and verbal descriptions. These include:

1. Distorting Mirrors (Traub & Orbach, 1964)
2. Anamorphic lenses (Glucksman, 1969)
3. Verbal description, questionnaires and silhouette matching (McElhone, Kearney, Giachetti, & Zunft, 1999) (Cachelin, 2006) (Berg, Paxton, Keery, Wall, & Guo, 2007) (Kagawa, Kuroiwa, Uenishi, Mori, Dhaliwal, & Hills, 2007)

(Each of the above examples is briefly described)

Traub and Orbach investigated obese patients’ perception of their own body size, using apparatus specially modified to manipulate body size and measure body size perception. The conclusions drawn from this study indicated that obese patients overestimated their own body image during weight loss and also overestimated the size of external objects. On the other hand the study noted that observers who were not obese and maintained their weight during the study had a more realistic perception of body image and also a realistic perception of external objects. This suggested that an observer with an unrealistic over estimation of their own body image will also perceive others and objects as having increased size (Traub & Orbach, 1964).

Glucksman used a Hilux 102 variable anamorphic lens to perform their body size experiments. The lens was attached to a modified slide projector that could distort an image either way, making it bigger or smaller. The dial had ten points on it, the midpoint showing an undistorted image. The participants of the

experiment were not allowed to observe the dial and so were unaware if the image was distorted or not. Through a combination of diet and once weekly visual testing of the participants own body through the lens, body size was measured. A size estimation score was used over four trials for each participant. The results varied depending on the weight of the participant. Underestimation of body size was significant in non obese participants and overestimation was significant in obese participants (Glucksman and Hirsch, 1969).

Freeman et al (1984) cites Freeman et al's (1983) four categories of measuring body image as
" inferential, drawing, analogue and optical distortion methods" (p411)

In their paper describing the use of video camera techniques for measuring anorexic and bulimic patients' body image they describe a new method using two video cameras which give a front and profile view which had not been looked at before, therefore giving a whole body view rather than just face on (Freeman et al 1984).

Body image perception has since been explored using less high tech methods in the form of questionnaires and surveys. McElhone et al (1999) used an interview assisted, face to face survey to establish differences in body image perception in Europe. 15 different EU states between March and April 1997 were covered in the survey. Less than half participants in the EU were satisfied with their appearance when asked, 46% of males were satisfied and 31% of females were satisfied. This suggests that females have lower body satisfaction than males. Underweight females showed the biggest percentage of participants who were satisfied with their image at 58% and 66% of males who were a normal weight were satisfied with their image. The conclusion was that there are clear gender differences in body satisfaction and underweight females are more content than normal females and overweight females predominantly see themselves as bigger than they actually are (McElhone et al 1999).

Similarities between perceived body size ideals and the body shape of 'Barbie' and 'Ken' dolls have been shown to have effects on self image from a young age (Norton et al 1996). In Norton's study the dolls were scaled up to human size and compared with actual human adults. Although both Barbie and Ken were classed as thin Barbie was significantly less realistic than Ken. The probability of finding a human of the same size as Ken would be 1 in 50 but only 1 in 100,000 women would have Barbie's dimensions (Norton et al 1996).

Parallels can also be drawn between low self esteem and poor body image resulting in a vicious circle (Berscheid, 1974) (Traub & Orbach, 1964). Berscheid suggested that one possible hypothesis could be that those considering themselves 'less attractive' are more likely to request psychotherapy. The obsession we have regarding the way we look could be because we are eternally judging the bodies we look at and therefore know instinctively that others are judging us (Saltzberg, 1995).

The context study has revealed the continuing importance of body image and how it can be manipulated. The main focus of this study will concentrate on monochromatic optical pattern rather than garment shape as the professional design background and discipline of the researcher is in this area and the existing research lends itself to optical manipulation of size perception.

1.4 Black, white or pattern?

1.4.1 *Existing research on how pattern can affect the perception of body size*

Very little evidence was available that detailed research in the area of how pattern can affect the perception of body size. There have been two notable studies carried out by Imai (1982) and Sai et al (1998) where stripes have been tentatively tested to see if they make a body look smaller or bigger. These studies are discussed further below.

Frith and Gleeson (2008) discuss the gap in research regarding the clothed body and the importance of looking at positive body image as well as negative body image, which has dominated the literature researched during this study.

Their paper into the way in which women dress themselves to appropriate a desired body image gives significance and validity to the main aims of this study.

“research tends to focus on behaviours which are potentially injurious to health (such as restricted eating, laxative and steroid use, and excessive exercise) rather than on grooming and more mundane appearance-modifying behaviours (such as hairstyling, self-care, and dress).” (Frith and Gleeson, 2008, p251)

1.4.2 *Popular media factors affecting the way we see ourselves*

"Of all the offspring of Time, Error is the most ancient, and is so old and familiar an acquaintance, that Truth, when discovered, comes upon most of us like an intruder, and meets the intruder's welcome." (MacKay 1850, p208).

This thesis is concerned with providing an evidential basis for the influence of monochromatic optical pattern on the perception of the female form. It is considered important, therefore, to discuss here the influence of the media on peoples’ beliefs of how the female form can be positively camouflaged by using certain monochromatic optical pattern effects.

Because media and marketing of ideas has served to influence and control choices that humans have made for centuries, people tend to believe what they are told and are often guilty of following the crowd (Thaler & Sunstein, 2008).

The belief that horizontal stripes will make an object look wider or fatter and vertical stripes will make an object look longer, taller or thinner has been investigated and disproved almost 150 years ago (Helmholtz, 1856), yet when this is applied in a fashion context, we tend to believe what fashion writers in the media have told us and stick to the original misconception. Is this a misconception? Imai and Sai et al cited by Taya and Miura (2007) supported the common belief that vertical stripes would make a person look thinner than horizontal stripes. This contradicts Helmholtz’s claims in the mid 1800’s. Research by Thompson (2007) once again reversed the claims of Imai and Sai in support of Helmholtz. What else have we been told and believe just because

we believe what the recognised authority on a subject told us? Blood (2005) states,

"The authority to speak 'truthfully' about women and women's body image problems is overwhelmingly accorded to psychologists. Psychological 'truths' and facts are characterised by the introduction and use of a language of body image, a set of norms, an assortment of technologies and a plethora of 'experts'". (Blood, 2005, p.91)

The quote from Blood is explored in more detail relating to the effects of advertising on consumer choice detailed in the next paragraph.

This section summarises the key developments in our understanding of how consumers make choices, how advertising works and how we can be more aware of how to obtain true facts through real evidence about how pattern affects perception of body size. The following discussion is relevant to this study since advertising influences the way consumers perceive their bodies and also how they can achieve the ideal body shape presented in the media.

Body image and body size is a major topic in fashion and lifestyle magazines, television and radio. Advertising also provides visual examples of body image and body size. This can lead to a conscious and sub-conscious need and desire for humans, mainly females, to try to conform to what is seen as the body size 'ideal' (McElhone et al, 1999). This 'ideal' has been reported as being thinner than average (Cusumano, 1997). Norton et al (1996) suggests that the idea of the ideal body seen in magazines can mostly be attributed to the shape and size of fashion models (Norton et al, 1996). The influence of fashion models in the media is having an effect on what the perfect body shape is. Historically women have been the main focus when it has come to the debate on size zero models. Dugan (2008) has reported an increasing trend for size zero male models. He discusses a new wave of "stick thin men" walking the catwalks at London fashion week, which is a noticeable change from the more muscular male models that have dominated the catwalks of the previous two decades. Dugan states "it heralds an era where men – like women – feel pressure to conform to a waif-like body image". He also quotes a spokesman from the eating disorder charity Beat, saying that "There does seem to be a growing trend towards men's clothes being designed for the

slimmer male physique" (Dugan, 2008). The recent banning of the use of size zero fashion models is having potentially different effects from those intended by increasing the amount of media coverage that this issue attracts daily. Fashion and gossip magazines show that celebrities and models are reducing in size. Debenhams blog reports that as a nation we are getting heavier, evidenced by the fact that the average British woman is a size 16. In response Debenhams Department Store has recently started using size 16 dummies to display their clothes (Debenhams Blog, 2010).

The ideal female form is universally perceived in the west as having large breasts and small hips (Norton, Olds, Olive, & Dank, 1996). This ideal also relates to the possible influence of the Barbie doll having a sub-conscious effect on young women leading them to expect an unrealistic body shape later in life (Norton et al 1996). When a desired body shape is not achievable a negative body image can occur. A significant and recurring finding is the increasing trend of negative body perception (Finegan, Borland & Marco 2007). This evidence is backed up by a survey conducted with 25,000 radio listeners (BBC, 2007). It found that 32% of the sample would like liposuction in order to decrease body parts with which they were dissatisfied (Finegan et al 2007). However some of the media have focussed on rectifying the ever present thin 'ideal'. Television programmes like 'How to Look Good naked' with Gok Wan (How To Look Good Naked, BBC, 2006-present) look at the insecurities people have and try to increase confidence in the areas that look great, therefore changing personal perceptions. The understanding of certain areas of the body that are perceived as 'problems' by women could be the areas that monochromatic optical pattern should be concentrated on camouflaging. This study aims to identify observers' perceptions of size and relevant ways of changing that perception.

In British and American culture the 'look' that many women desire is closely related to what is seen in fashion magazines and men's glamour magazines such as Playboy. There has been much research into body image and body shape ideals of the last 50 years. Garner, Garfinkel, Schwartz and Thompson (1980) researched the changing shape of Playboy centrefolds over a 20 year period (1959-1978). They found that as the models increased in height over

the 20 year span and their hip and bust measurements decreased. The mean weight of the centrefolds was significantly lower than that of an average female over the same time period. In addition to this aspect of the study, six popular women's magazines (Harper's Bazaar, Vogue, McCalls, Good Housekeeping, Ladies Home Journal, and Women's Day) were studied over the same time span and it was discovered that there was a significant increase in the number of articles on dieting. This research was carried out again over a 10 year span (1979-1988) by Wiseman et al (1992). Results were that bust and hip measurements continued to decrease.

Nemeroff et al (1994) carried out research on the number of weight loss, beauty, health and fitness articles carried by several different men's and women's magazines. Fashion magazines were seen to contain the most body-shape oriented imagery and articles, thus continuing the increasing coverage of the body 'ideal'. The body 'ideal' in most cases being on the 'thinner is more beautiful' end of the scale.

1.5 Summary

The desire to manipulate the perceptions of one's body is not new. It has existed in many forms globally and throughout history. Recent media interest in the topic of body size has stimulated this research and this study develops the research begun by Macintyre's initial studies into drape on bottoms.
This chapter has summarised some of the psychological context of the topic of perception of body image. Popular media's influence on body image has also been examined.

Two important factors have emerged from initial reading. Women are willing to go to extraordinary lengths to achieve their desired body image. This will be either through enhancement surgery involving breast implants, bottom implants and liposuction/sculpting or by extreme dieting and control undergarments.

If it is the case that women want to look thinner to be fashionable, then monochromatic optical pattern may be able to achieve that rather than unhealthy dieting and body modification surgery. This study will evaluate the

perceived effects of monochromatic optical surface pattern on the female form. A body of data will be collected to support the use of visual means to change perception along with a body of tested designs/monochromatic optical patterns that will manipulate the perceived size of an object/body.

This research focuses on potential monochromatic optical patterns that could camouflage particular aspects of a female form when clothed, but it does not condone the pursuit of an unrealistic body shape. This research aims primarily to establish whether or not the claims made in women's media of what makes a person look a certain way are true or false. For example it is commonly reported that wearing black makes a person look smaller, wearing white makes a person look bigger and large scale floral patterns can disguise or camouflage bigger sizes.

It has been concluded that no rigorous research has been reported in psychological studies or popular media regarding the effects of pattern on perceived female form, however, it has highlighted the obsession with body shape. This conclusion has directed the line of enquiry detailed in the next chapter.

This study takes a textile designer's viewpoint and direction to try and establish scientific and design outcomes to determine whether a change in size perception can be achieved through optical monochromatic printed textiles.

1.6 Aims and Objectives

1.6.1 *Aims*

1. To establish the current state of knowledge regarding the manipulation of human perception of female form and how the perception of size has been measured or quantified.
2. To develop a method of measuring perceived differences in size of a printed image/object.
3. To investigate the influence of surface printed monochromatic optical pattern on the human perception of size
4. To create a conceptual design collection that demonstrates the perception of size caused by the optical effects of printed design on textiles.

1.6.2 *Objectives*

1. To establish the current state of knowledge regarding the manipulation of human perception of female form and how the perception of size has been measured or quantified. The following objectives will be followed:

- Establish the methods that have been used in art, science and fashion to manipulate an observer's perception of an object's size through the use of pattern
- Establish previous methods used to measure the perception of the female form
- Identify relevant known research looking at perceived body shape
- Establish known optical effects and patterns used in fashion, art and design to create an illusion for the observer

2. To develop a method of measuring perceived differences in size of a printed image/object, the following objectives will be followed:

- Evaluate paired comparison and ranking methods for reproducibility and consistency
- Develop a new method of quantifying human perception of size and rating differences in perceived size of flat printed objects

- Establish a scientific method to test the validity of current fashion tips and tricks using a paired comparison method
- Establish an optimum sample size for each perception study/evaluation

3. To investigate the influence of printed monochromatic optical pattern on the human perception of female form, the following objectives will be followed:

- Establish the shape best suited for garment designs
- Establish the effect of changing monochromatic optical pattern placement on the perceived size of an object
- Test appropriate illusion theories in a fashion context
- Explore designs in monochrome

4. To create a conceptual design collection that demonstrates the distorted perception of size caused by optical effects of printed design on textiles, the following objectives will be followed:

- Develop printed textile designs using known optical illusions with a view to changing perception of size through optical illusion on 2D flat designs
- Print a range of optical fabrics constructed as garments to demonstrate the concept of an illusion relating to perception of size
- Project, collate and photograph monochromatic optical patterns to produce a record of the conceptual practice of capturing design on the female form
- Show development of the collection and design process in a visual form

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Chapter 2 – Methodology/ The Design Process

2.1 Introduction and research questions

This chapter describes and discusses the different methodologies used for measuring perception and evaluating designs throughout this study, and how these formed part of the design process.

The starting point for this research was an initial set of visual samples taken from unpublished work into fabric drape on women's bottoms carried out by a group of students led by Dr Lisa Macintyre (2005). These samples are used to familiarise the researcher with testing techniques that were used previously for Macintyre's project. As Macintyre's project was the basis for some of this study's aims, her techniques are developed to create an appropriate new method. These preliminary tests are also used as a method of directing the literature review. The original samples, which are described in more detail in Chapter 4, used a paired comparison method using picture cards to obtain observers perceptions of differing sizes of shapes.

The following research questions were developed in relation to the aims and objectives for the project and emerged from a thorough literature search. They were answered throughout the course of the research through various methods which related to the different stages of the design process:

- What is the current state of knowledge regarding the manipulation of perception of female form and how can the perception of size has been measured or quantified?
- What methods have been used in art, science and fashion to manipulate observer's perception of an object's size through the use of pattern?
- Which methods have been used to measure the perception of female body size?
- Are there any relevant known studies looking at perceived female form?
- Which known optical effects and patterns used in fashion, art and design create an illusion for the observer?

- Is it possible to develop a method of measuring perceived differences in size of a printed image/object?
- Is it possible to develop a new method of quantifying human perception of size and rating differences in perceived size of flat printed objects by means of a new method?
- Using paired comparison method, can any scientific method to test the validity of current fashion tips and tricks?
- What is the best suited shape for garment designs?
- What is the effect of changing monochromatic optical pattern placement on the perceived size of an object?
- What factors must a conceptual design collection consider, to demonstrate the distortion of perception of size caused by the optical effects of printed design on textiles?
- Is it possible to show a change in perception of size through optical illusion on 2D flat designs?
- Is it possible to print a range of optical fabrics and construct them into garments to demonstrate an illusion relating to perception of size?

2.2 The process of the study

This is a mixed methods' study incorporating quantitative, qualitative and tacit research. Mixed methods' research makes the basis of the study more robust by bringing findings from different approaches to the issue of perception of the female form. During the course of this research, several methods are explored to ascertain whether perceptions of size can be measured, the different paradigms are then triangulated to give weight to the outcomes.

The sequence of the study follows traditional lines of research design. First a thorough literature review is conducted and is added to throughout the study as new lines of enquiry open up and as the currency of the body of knowledge needs to be updated. Second, quantitative methods of measuring perception are employed in order to come to a final choice of method. Tacit knowledge informs the design of a dress to be used to test the emerging theories. Finally, designs developed via tacit methods are displayed in such a manner as to be

published into surveys that can be trialed on observers and both quantitative and qualitative data are gathered.

2.2.1 *Triangulation*

In this study triangulation of methods is used to increase the validity of the findings (Denzin and Lincoln, 2005). Till (2005), writing on architectural research, describes a new model of research developed by Professor Bryan Lawson at the University of Salford. Lawson's model influenced the mixing of methods for this study. The model, which was developed for architectural research, was one that enabled a science and art, qualitative and quantitative process to be undertaken in the course of one study where each process informs the other. "Most importantly the model also describes architecture temporally (as opposed to a set of static fragments), with one stage leading to another and, crucially, creating an iterative loop in which one stage is informed by another. For research to be most effective, and thus for [architectural] knowledge to develop, it has to feed this loop." (Till 2005). This paradigm can also be applied to textile design research.

Lawson's model is divided into three stages: Processes, Products and Performance. This relates to the methods used in this study in the following way:

- The process stage concerns design and construction and therefore would involve topics such as theories of design and effects of the environment. In this project this stage is exemplified by the quantitative process to test initial theories. This first stage of this research which experimented with different methods of acquiring perceptions of size from observers is clearly related to Lawson's design and construct stage.
- The product stage then looks into the design as a completed item or product and concerns itself with aesthetics, materials and techniques that have been used to create the product. In this project the product can be identified as the paired comparison method. At this stage of the project, the decision is made to move from the closet of Heriot Watt University Scottish Borders Campus (HWUSBC) to Bristol Online Survey (BOS) which is published on the World Wide Web (WWW). The decision is a

result of an examination of the aesthetics of the research design, the choosing of the materials required to construct and present images for comparison and a consideration of the techniques employed to give the best possible images for reliable results.

- The performance stage looks into the design or product once it has been completed and therefore looks at its performance and impact on its environment and its cultural assimilation. In this project this stage is exemplified by the iterative process and the methods used to test the dress design. The dress is presented to a sample of observers and its impact is assessed in terms of how easy observers found it to identify perceived differences in size.

2.3 The literature review

The literature review aims to establish the current state of knowledge regarding the manipulation of human perception of female form and how this change in perceived size is measured or quantified. The following searches are undertaken and explored:

- Existing research on human perception of female body size
- Existing research on how pattern can affect the perception of the female form
- Psychological studies of factors affecting the way we see ourselves
- Popular media factors affecting the way we see ourselves.

It is clear from an extensive search of publications that there is little scientific research in the area of how printed pattern affects one's perception of the female form. This then leads to another avenue of exploration and a Chapter on inspiration is formulated. This Chapter looks in more depth at the theories of illusion and deception as well as how artists use pattern to create distortion through colour and line. The following topics are explored:

- Perception and illusion,
- Optical illusion,
- Size illusion created through line,
- Organic pattern (camouflage),
- The use of shadow and shading to conceal,

- Illusion in art and design

2.4 Quantitative research: rating; ranking; paired comparison

In the first instance quantitative research is undertaken to develop a method of measuring perceived differences in size of a printed image/object and to investigate the influence of surface printed pattern on the human perception of size. Initially the sample size is small due to the limited availability of observers and to manage the cumbersome nature of the physical testing set up.

Initial tests are carried out to determine the best method for showing visual samples to observers. These observers are members of staff and students from Heriot Watt University. Three methods, rating, ranking and paired comparison are tested to determine the best way in which to present visual samples to the observers.

After the original samples are tested two new sets of samples are designed and produced for the purpose of this research, these are identical to each other. The new samples are made bigger than the initial samples used in previous research and are also produced in black and grey relating to Helmholtz theories of colour and irradiation illusion effects. The visual samples consist of 13 printed square grey cards with internal black squares of which the dimensions range from 19.5cm to 20.5cm increasing in 1mm increments.

Three methods of evaluation are used for the next experiments using observers. Paired comparison, ranking and rating (using a newly devised scale) methods are performed in a darkened room within a Light box cabinet with the black and grey samples. Observers made up of staff and students of Heriot Watt University are invited to take part in several observation exercises. The sample size ranges from 5 to 12. This relatively small number of observers gave qualitative feedback throughout the process and their repeated availability is key to the study. Observers are asked to rank, compare and rate visual samples from 7 out of the 11 standards. Each visual sample is used to test observers' ability to perceive a difference of 4, 3, 2 and 1mm respectively.

A set of visual samples is used for the ranking method. Different sized internal squares are ranked from smallest to biggest until there is an order present of smallest on the left to biggest on the right. Individual responses are recorded where the internal square identified as 'smallest' is placed on the left, then the next smallest is on the right of the smallest, then the midsized square is next on the right, then the second biggest is next on the right and the biggest is after that on the far right hand side (see Chapter 4).

Once again a set of visual samples is used for the paired comparison method of evaluation. This method is used to determine which out of 2 visual samples the observer finds bigger. The observer is shown 2 visual samples either of different internal sized squares or identical internal sized squares and asked to point to the sample which has the biggest internal black square (see Chapter 4).

The rating method is devised to see whether or not a method of rating similar to a grey scale can be used to measure observers' perception of differing sizes.

For the purposes of this research this method of rating with a size scale requires a name similar to 'The Grey Scale', therefore the size scale set of samples is called the Caltyre scale. The name is derived from Lynsey Calder and Lisa MacIntyre's surnames to convey the collaborative test design at this stage. Observers are asked to rate different sizes of visual sample. In these initial experiments 4 limited Caltyre scales with only 7 standards each are used to test observers' ability to perceive a difference of 4, 3, 2 and 1mm respectively. This matches the ranking and paired comparison tests.

A second version of the Caltyre rating scale is devised and is performed in a similar way to the first version. Version 2 of the Caltyre scale uses the same visual samples and Caltyre scale standards that are described in Section 4.2.6, but is presented in a different way from version 1.

Quantitative research using between 5 and 12 observers, is used to establish whether paired, ranking or rating methods are the most reliable and suitable ways in which to determine whether a small difference in size could be

detected by observers. This method of asking participants what their perceptions are in a structured, scientific manner helps the collation of data which can then be analysed.

After rigorous testing of three methods - rating with the Caltyre scale, paired comparison and ranking, it was concluded that the best overall method for this research is paired comparison. This conclusion is based on the following:

- Observers found this method of visual assessment the simplest to understand and the fastest to perform.
- Whether they were required to rank the samples from smallest to largest, or, later, when they were being asked to rate samples against the Caltyre scale, observers tended to use an informal method of paired comparison regardless of instruction, to come to their conclusions.

In response to the qualitative comments that resulted from the experiments performed in the closet, it was decided that a computer based survey would be more beneficial and could yield higher numbers of observers. This was due to the time taken to perform each of these tests and the availability of observers. Initial designs comparing visual samples of plain black squares and monochromatic optical patterned squares were set up using Microsoft Power Point and a desktop survey was produced.

These conclusions are discussed further in Chapter 5 and Chapter 6.

2.5 Quantitative methods – moving from the dark room to web based surveys

One key aim of this research project is to find a method by which the effects of monochromatic optical pattern and the perception of the female form can be understood. The most appropriate method is sought for investigating the influence of surface printed monochromatic optical pattern on the human perception of size, and by creating a conceptual design collection to demonstrate the perception of size caused by the optical effects of printed design on textiles.

Great care is taken to fully investigate scientific methods employed by previous research, and the method of paired comparison proves to be of most value to the key aim of designing a collection which could be presented and evaluated to the greatest effect.

This traditional research paradigm is used to establish the best possible method for presenting images with size difference to observers. At this stage of the research, qualitative comments collected from observers during and after the physical testing which is performed in a small darkroom (the closet) at Heriot Watt University's Scottish Borders campus, are evaluated and, based on this evaluation, a new approach to the overall presentation and direction of the research is developed through a tacit and iterative process. The scientific work, therefore, acted as a filter of methods and as an experimental process leading to a design based approach resulting in quantitative web based questionnaires.

The decision to move from the closet (HWUSBC) to using Bristol Online Surveys (BOS) and publishing on the World Wide Web (WWW) (see section below) is not only a designer decision but is also made in order to consider the type of observer that is required for the nature of the tests. The next stage of testing and the aesthetic of the images requires a type of participant who is interested in visual culture, fashion and perception - the kind of person who uses the internet on a daily basis and who is within the researcher's immediate and wider circle of contacts. These participants are appreciative of the nuances of design and are more easily accessible online than by other, more traditional contact. To protect the integrity of this study it is important to have responses from social networkers, IT savvy fashionistas and interested parties using a simulated situation in which they are comfortable and skilled.

2.6 Design development: tacit research

As outlined above, the method of looking at and judging differences in size has been established and it is now important to provide a visual aesthetic which appeals to the IT fashionistas and observers interested in perception and fashion. An approach based on tacit research is chosen as it is considered that

it will appeal to the constituency in which the researcher will find her sample. The use of a tacit method is also a very suitable approach for the kind of research described in this thesis. As a designer this is a natural step and the processes that are undertaken are explained fully in Chapter 5. As Barrett (2006) asserted “Because creative arts research is often motivated by emotional, personal and subjective concerns, it operates not only on the basis of explicit and exact knowledge, but also on that of tacit knowledge.” (Barret, 2006).

After the testing phase in the closet a set of monochromatic optical patterns were designed and tested using Microsoft Power Point on a desktop computer as a pilot web based survey using monochromatic optical patterns. As an experienced textile designer, the researcher was skilled in employing tacit research techniques involving a process of ‘blind faith’ and ‘experimentation’ (Barret, 2006). This approach led to designs influenced directly by optical illusions. This method is also a way in which to carry out studies involving monochromatic optical patterns developed from Helmholtz and Itten’s theories on optical illusions and effects, and to experiment with which monochromatic optical patterns and designs ought to be taken forward. This instinctive method of research is used during the phase of experimentation. Using Hering Illusions on a dress to ascertain whether or not they would create similar effects is a purely experimental decision. The instinctive process of a designer to just know how something will work is relied upon for these decisions.

These processes can be seen as research in several different ways. Till (2005) discussed three myths which are seen to hold back architectural research. The same conclusions can be drawn for design research. Myth three which discusses the theory that building a building is research can be related to the belief that designing a design or textile or pattern is research. Till’s definition of research that “It is compelling enough an argument to allow generations of architects (as well as designers and artists) to feel confident in saying that the very act of making is sufficient in terms of research, and then to argue that the evidence is in front of all our eyes to see if we would just choose to look.” is used here to justify the tacit approach taken. Research is seen here as implicit in the processes of designing. Experimentation and a purely practice based

approach is rejected in favour of "systematic inquiry whose goal is communicable knowledge" (Archer quoted in Till). It is, therefore, argued here that, by mixing three different types of research in this study, a systematic approach is taken and that issues surrounding the validity of the instinctive process of tacit research/knowledge are avoided. This use of tacit knowledge to explore design ideas is articulated into explicit knowledge in Chapter 5.

2.7 Quantitative and qualitative research: the survey

The final method formulates the designs that are explored tacitly and displays them in such a manner that can be published into surveys that can be trialed by observers. The use of surveys can be justified in the following terms:

Since there are no current theories to explain how changing a print on a garment can change one's perception of someone's size, the problem identified in the research questions needs to be explored and a tentative theory developed. Most of the available literature is concerned with psychological reasons for changes in body perception to do with eating disorders and body dimorphic conditions, so the emphasis in the literature is about perception of oneself and not of others. Little scientific literature on changes in body perception set in a fashion context exists. Most of the literature concerning fashion and size centers on ideas of what makes a person look big or not, but none of it is scientifically backed up. A close up view of the issue is required in order to understand this phenomenon. This close up view had not yet been undertaken by researchers. A survey can provide this detailed view in the choices made by respondents and in their comments.

To ensure reliable results a high number of observers are required (Cryer 2006). The volume of observers needed can be most easily contacted electronically, this method of observer selection is used to present paired comparison in a web based format. Using BOS and rolling it out using the WWW offers great new avenues for greater numbers of observers.

For the purposes of this study an experimental dress is designed and made. Photographs are taken of the dress with different monochromatic optical

patterns projected onto it and then manipulated using Adobe Photoshop and uploaded to Photobucket, an image hosting website (www.photobucket.com). Photobucket is used as it provides a simple way of transferring images created in Adobe Photoshop into a format that can be easily uploaded to websites. It is also the most cost effective way known to the researcher as it is free. These images are then uploaded to Bristol Online Survey (BOS) where a web survey is built. BOS is used as it offers a way of building surveys that can be easily distributed via email and posted on websites. It is relatively simple to use and it has the ability to host images. Four surveys are built and published online in an iterative process.

Once the method is determined and its challenges are explored, the following steps are undertaken: In order to approximate differences in female body size, dress samples are designed and constructed so that it can be assessed whether observers can correctly detect differences in size when shown monochromatic optical patterns on dress shapes.

BOS is used as a simple way of building a straightforward, paired comparison survey where pairs of projected monochromatic optical pattern dresses can be evaluated and judged by the maximum number of observers possible in a short period of time.

During the course of this research students of Heriot Watt and other universities as well as members of the general public are asked to take part in visual tests and surveys. Participants are asked to observe samples and images in different situations and formats to ascertain the most reliable methods of collating data from varying sample sizes. The final round of testing is distributed via electronic means and is sent as a mail shot to Heriot Watt University and Glasgow University students, it is also sent to all the researcher's email contacts which include family, friends and colleagues, as well as being published on a blog and on Facebook. The sample size of 300 on average and varied demographic of the observers is considered to be a fair representation of opinions and perceptions held by the kind of people interested in fashion and the subject of this study as they were self selecting.

2.8 Provisions for trustworthiness

Several aspects of the design of this study increase the validity or trustworthiness of the study. First, a quantitative method of data collection is used, that is, testing observers' perception of size. Second an examination of literature to analyse the scientific knowledge in the subject area is carried out. Third a tacit approach to monochromatic optical pattern design in a fashion context is employed. Fourth, outcomes are presented to participants, and these are tested in an iterative manner through a survey. Fifth, designs and methods for capturing designs are recorded in the form of a Digital Sketchbook to provide a visual representation of the designs validating the tacit methods. Finally triangulation of the data, methodology and perspectives is used to enhance the rigour of the research.

2.9 Summary

This chapter has set out the methods used in this study. It is a mixed methods' study combining quantitative, qualitative and tacit research to achieve triangulation and robust results.

The next chapter examines the existing and relevant knowledge on pattern and line in terms of illusion and camouflage. The analysis of this knowledge is used as primary data to give a better understanding of the workings of illusions and is used as a basis for this study. This design approach to the research is used as the starting point for experiments carried out further on in this study.

2.10 References

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CHAPTER 3 – Perception and Illusion/An Overview of Inspirations

“ We take pleasure in being visually deceived and we often choose to subject our senses to special kinds of optical stimulation. We delight in disturbing and testing the outer limits of visual tension and balance. We enjoy reflecting on our own mental and visual processes as they become an extension of a work of art.” (Carraher, 1966, p.9)

The first part of this Chapter discusses the basics of perception and illusion and the optical illusions that were first discussed by German physiologist Karl Ewald Konstantin Hering (Robinson, 1998), German physician and physicist Hermann von Helmholtz (Robinson, 1998) and German psychologist and philosopher Wilhelm Maximilian Wundt (Robinson, 1998). As background, the work of Muller-Lyer, Ponzo, Ames and Opel-Kundt is briefly described.

The second part of this Chapter discusses the illusions and deception that can be created through camouflage both naturally occurring and also manmade, also known as Disruptive Pattern Material.

The third and final part of this chapter discuses illusion in art through Op Art and the works of Victor Vasarelly, Bridget Riley and Sarah Morris

The discussion in this chapter is important as it provides primary data to inform the design aspect of the present study. This is necessary since little literature exists on the specific effects of pattern and line in terms of illusion and camouflage on the perception of the size of the female form. This design approach to the research gives a basis for experiments carried out further on in this study.

3.1 Perception and illusion

The perceived size of an object is measured by more than how the eye sees it. An object is “seen” by being processed by both the retina and the brain. Light enters the eye and the image created on the retina is transferred to the brain

through the optic nerve. The brain processes the information, using previous experience, to produce an understanding of what has been "seen". Sometimes, because of this previous experience, the brain makes a false assumption about what is being transferred from the retina. This factor can be used to create optical illusions. (Gregory, 1998)

Gregory (1998) defines perception as an interpretation of a sense stimulus. His theory explains that our perception of an object is dependant on it's context and our schemata. (Gregory, 1998)

The size of an object on the retina is dependent on the distance between the object and the viewer's eye as well as the actual size of the object. The closer an object is to the viewer's eye the larger it will appear to be. Measuring the perceived size of an object is, therefore, dependent on the actual size of the object and the distance from the eye. This draws similarities between size and depth perception (Palmer, 1999) (Wade, 1990).

During the research, one factor which is considered is 'size constancy'. This means that an object that is familiar to the viewer will appear to be a constant size within a reasonable distance, however if the object is known and a significant distance away then it can appear very small. If you were looking at the street from the top of a skyscraper then people and cars appear as very small dots even though we know their actual size (Palmer, 1999)(Wade, 1990). This phenomenon informs design considerations discussed in Chapter 5.

3.2 Optical illusions

Optical illusion has been discussed in the literature since the mid 19th century by scientists such as Helmholtz, Hering and Oppel and Wundt (Robinson, 1998). After this time little to no interest in the subject area occurred until the mid 20th century. Robinson (1998) reported that the increasing popularity of OP Art in the 1960's generated a revival of interest in the subject area.

"Classification is a taxonomic exercise and does not itself provide explanations. It may help in the process of finding them by ordering the material in a way that

makes thinking easier, but it could also obscure important similarities or differences." (Robinson 1998, page 20).

Robinson (1998) discusses various different viewpoints regarding classification of illusions by Boring (1942), Luckiesh (1922), Oyama (1960) and Tolanski (1964) who all give different classifications and sub classifications for illusions. It is clear that there is no 'right' way to classify. For the purposes of this study the classification by Gregory et al (1995) will be used and is explained below.

A number of size illusions have been demonstrated in different visual ways. Illusions can be classified in three different categories - Physical Ambiguities, Physiological Ambiguities and Cognitive Ambiguities (Gregory et al, 1995).

A selection of optical illusions have been looked at specifically for the purpose of this research.

The Muller-Lyer Illusion (Figure 3.1)

Ponzo Illusion (Figure 3.3)

The Hering Illusion (Figure 3.4)

The Wundt illusion (Figure 3.5)

The Helmholtz illusion (Figure 3.6)

The Ames Distorted Room (Figure 3.7)

3.2.1 *Cognitive ambiguities*

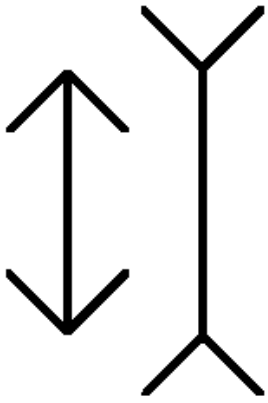

Figure 3.1 - The Muller-Lyer Illusion
(http://www.aber.ac.uk/media/Modules/MAinTV/Images/muller1.gif)

The Muller-Lyer Illusion is an example of a distortion in the cognitive ambiguities classification of Illusions (Gregory, 1995). There are many

explanations for how the illusion in Figure 3.1 works but the most popular explanation is that our brain makes mistakes about the relative depths of the two lines. This illusion comes under the classification of 'illusions of extent' where size or length is misjudged (Robinson, 1998).

In Figure 3.2 the Muller Lyer Illusion can be seen in context. We are used to seeing outside corners of buildings with lines sloping inward away from them. In these situations, from previous experience, the brain knows that the line running down the outside corner is the closest part of the image to us. The brain realises that this line is really shorter than it appears when compared to the rest of the building see Figure 3.2. This phenomenon exemplifies Gregory's (1998) explanation that context is an important factor in how we interpret what we see.

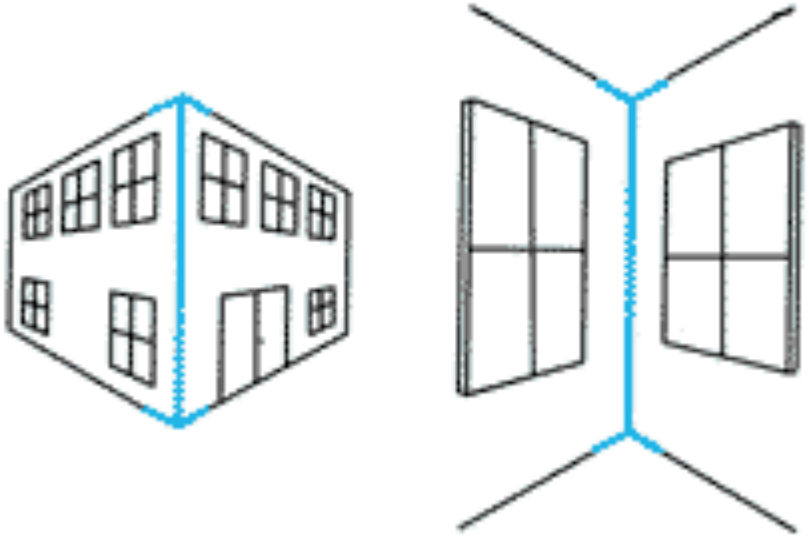

Figure 3.2 – Example of size perspective of inward and outward corner (http://www.rhsmpsychology.com/images/muller_lyer2.gif)

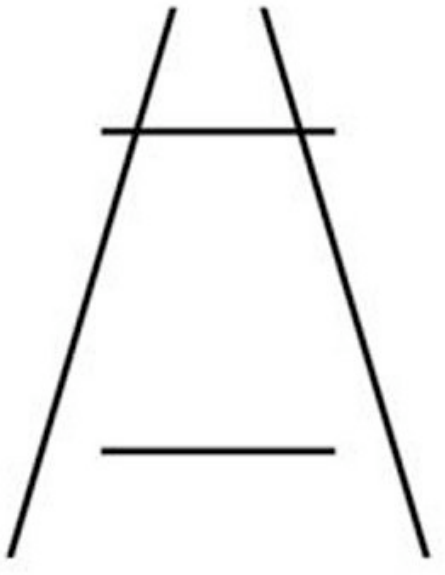

Figure 3.3 – The Ponzo Illusion
(http://1010living.com/blog/wp-content/uploads/2009/03/ponzo-illusion.jpg)

The Ponzo illusion shown in Figure 3.3 is another example of a cognitive ambiguity reliant on perspective to deceive the eye. Both lines appear to be different lengths but in actual fact they are the same. This is an optical illusion first demonstrated by Italian Psychologist Mario Ponzo in 1913. A common explanation for the Ponzo illusion is the 'Perspective hypothesis' which relates to the converging lines normally associated with distance. Another explanation is the 'Framing effects hypothesis' which relates to the spacing of the horizontal lines affecting the degree of distortion (Gregory R. L. 1998).

Both the Hering and Wundt Illusions are classed as cognitive ambiguities and come under distortions (Gregory, 1995). The Hering illusion, (Figure 3.4), gives the effect of parallel lines bending as they cross angled lines. This creates a distortion of perspective and a false impression of depth. The Wundt illusion is like the Hering illusion but in reverse. In this Illusion (Figure 3.5) the parallel lines appear to be bending inwards as they cross the angled lines of the diamond shape. These illusions are explored further in Chapter 5.

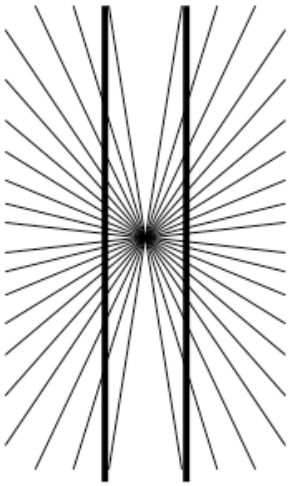

Figure 3.4 - Hering illusion

(http://images.braingle.com/images/illusions/26902.gif)

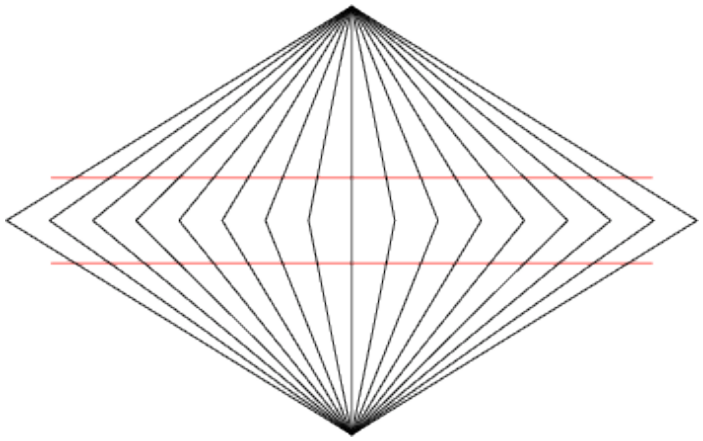

Figure 3.5 - The Wundt Illusion

(http://mathworld.wolfram.com/images/eps-gif/WundtIllusion_700.gif)

3.2.2 *Physical ambiguities*

The Helmholtz irradiation illusion shows two squares of identical sizes with internal squares of identical sizes. However, the white square within the black square appears bigger than the black square within the white square, see Figure 3.6. This effect known as irradiation occurs because the brighter white area "spreads" on the retina giving the illusion that it appears bigger than a corresponding square that is darker surrounded by light colour. This may explain the illusion of size difference between white and black, light and dark objects (Carraher, 1966). This is explored further in Chapter 5.

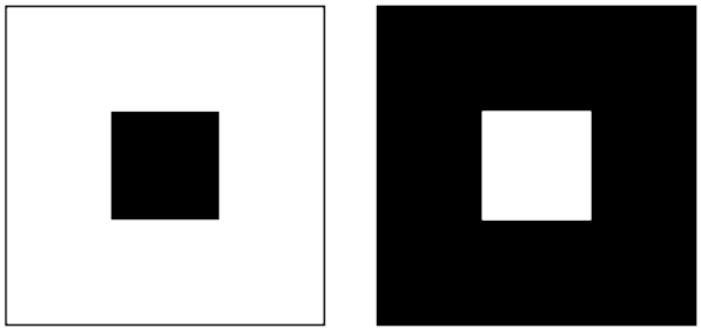

Figure 3.6 The Helmholtz irradiation illusion
(http://mathworld.wolfram.com/images/eps-gif/IrradiationIllusion_1000.gif)

3.2.3 *Physiological ambiguities*

An example of an optical illusion in the category of physiological ambiguity is the Ames Room which is classed as a distortion (Gregory, 1995). An Ames room is distorted to create an optical illusion of relative sizes (see Figure 3.7). The first Ames room was built in 1946, based on the late nineteenth century concept of German scientist Hermann von Helmholtz. When people or objects are viewed in an Ames room, there is a loss of normal perspective. An optical illusion is created for the viewer of the distorted room. Figure 3.8 shows two people standing in the Ames room. One person is standing in one corner and another in the other. The person standing in the right hand corner appears to the observer to be significantly larger than the person standing in the left hand corner while the room appears to the viewer to be a normal rectangular shape. This illusion indicates the significance of past experiences on how we interpret our perceived world. Bringing together different factors such as ambiguity, distortion, size constancy and context, the Ames Distorted Room is an example of various factors which result in an illusion for the viewer. These factors are important in this research and will be discussed in later chapters.

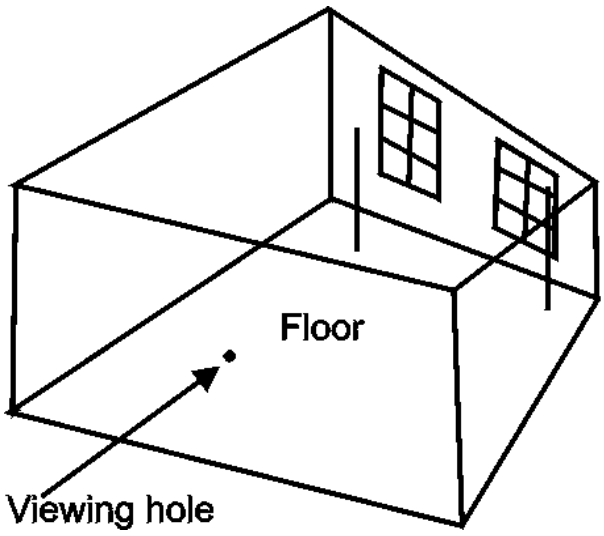

Figure 3.7 – The Ames Distorted Room
(http://www.yorku.ca/eye/Ame%20room%20diagram.gif

Figure 3.8 – The Ames Distorted Room
(http://www.wetcanvas.com/Community/images/19-Nov-2007/99109-Distorted_room.jpg)

3.3 Size illusion created through line

The illusions presented in Figures 3.1, 3.3, 3.4, 3.5, 3.6 and 3.7 are widely accepted and discussed in the literature. In this research project, the Hering and Wundt illusions and Helmhotz's theories of light and dark were developed into monochromatic optical patterns for use on fabric. These two illusions give

the impression of either concave parallel lines or convex parallel lines in a rectangular design which fit's the female form and the desired potential effects. The results of the experiments are discussed in chapters 5 and 6 and are shown in detail in the Digital Sketch Book.

The Oppel-Kundt Illusion demonstrates the phenomenon that when an area is filled with parallel lines it appears bigger than the same area empty of lines (see Figure 3.9).

Figure 3.9- Example of Oppel-Kundt illusion (http://biologija.kmu.lt/Images/RegLab/oppel_kundt.jpg)

The Helmholtz Square Illusion, see Figure 3.10, displays a similar distortion of reality as the Oppel-Kundt illusion. When a square is filled with horizontal lines the space appears taller than it's equivalent unfilled space. When a square is filled with vertical lines it appears as wider than it's equivalent unfilled space.

Figure 3.10 – Example of Helmholtz square illusion (http://www.visionsinternational.net/wp-content/uploads/2010/09/wpid-optical-illusions-14.gif)

Piaget and Bang (1961) noted that when subjects focused on the middle of the filled area of the Oppel-Kundt illusion the illusion remained strong; when they focused on the centre the illusion was weak; and when they focussed on the unfilled area they overestimated it's width and therefore the effects of the illusion was reversed. This highlights the importance of clear directions for the observer when undertaking experiments. This change in results shows the uncontrollable element in human perception which is discussed further in Chapter 6, section 6.3.

Robinson (1998) also discusses the difficulties of setting up experiments using the Helmholtz Square since the effects of the illusion vary with the number and width of the lines; the size of the square they are contained within and the distance from the observer.

The observations made by Piaget and Bang (1961) and Robinson (1998) impact significantly on this research. In popular media, women are often counselled to avoid wearing horizontal stripes because they will tend to make them look wider and therefore fatter than they actually are. This advice appears to contradict the effects of these two well-known illusions: Firstly, the Oppel-Kundt illusion (Figure 3.9) shows that a filled area looks longer than an unfilled area of the same size and secondly the Helmholtz square illusion seen in Figure 3.10 shows that a square comprising horizontal lines appears taller and narrower than one of identical size comprising vertical lines. These effects are very closely related and both suggest that, in contrast to the advice given in popular media, the wearing of horizontally striped clothes should make us look taller and thinner. Indeed Helmholtz quoted by Thompson (2007) claimed that 'ladies' frocks with cross stripes on them make the figure look taller".

Alternatively, Taya and Miura (2005) report previous research by Imai (1982) and Sai et al (1998) both of which support the received wisdom that wearing vertical stripes will in fact make you look slimmer and wearing horizontal stripes will make you look fatter. The Imai and Sai et al experiments were carried out using men dressed in striped or black suits.

Taya and Miura went on to investigate why a 2D illusion was reversed when applied to a 3D form. It is this 2D to 3D phenomenon that is discussed in this research further in Chapters 5 and 6. The illusions which are investigated in designs are the Hering and Wundt illusions (Figure 3.11). The Hering and Wundt illusions are used as the main designs in this study due to their simplistic design creating maximum impact in a monochromatic optical pattern which is simple to replicate as printed fabric. Results of the investigation are described and discussed in Chapters 5 and 6.

The two monochromatic optical patterns which distort perception using lines are the Hering illusion and the Wundt illusion (see Figure 3.11) which give the effect of parallel lines curving depending on which way diagonal lines are crossing them. Carraher (1966) notes Hering's 'illusion of direction' as vertical parallel lines appearing to bulge in the middle at the point where the diagonal lines converge. Carraher (1966) notes that Wundt's 'illusion of direction' depends on the diagonal lines converging outside the parallel lines and thus creating the illusion of diverging parallel lines.

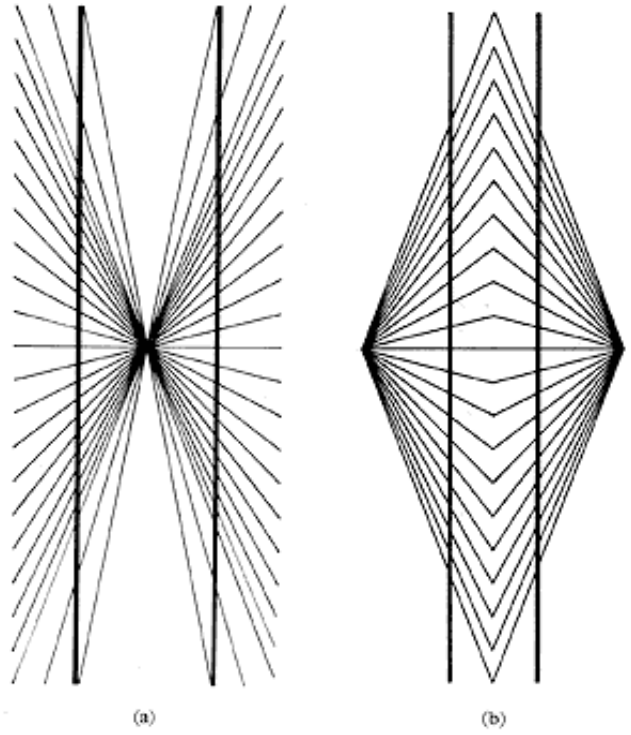

Figure 3.11– (a) Hering and (b) Wundt illusions
(http://www.richardgregory.org/papers/brainmodels/brain_model_fig4.gif)

These two illusions provided the initial inspiration for designs explored in Chapter 5.

3.4 Organic pattern (camouflage)

Organic pattern can be described as pattern that is visually chaotic or biometric, for example, camouflage. Camouflage or 'disruptive pattern' plays a major role in illusion and distorts the perception of size, space, distance and shape (Blechman, 2004).

3.4.1 *Camouflage in nature*

In a recent study into how animals use camouflage to change their perceived size and shape, it was noted that the use of high contrast markings at the edge of the animal's body served to disrupt the shape and outline of the animal (Stevens, 2009). True body shape is then distorted therefore creating a false impression of the real size of the animal. However, extensive research (Braddick, 1995) into camouflage reveals that in the case of animals in the wild these markings will serve to deceive when the animal is still. As soon as there is movement the predator can then detect prey when the visible edge is revealed. Similar principles were adopted for the first Dazzle camouflage used on ships in the first world war (see below).

3.4.2 *Camouflage in the military*

DPM (Disruptive Pattern Material) is the current official British military term when referring to camouflage material. Camouflage has been present in nature for millions of years; however the popularisation of camouflage pattern used by man has become more prevalent since the First World War, when it began to be used in a military context (Blechman, 2004).

There are 2 specific kinds of pattern, a traditional camouflage that is designed to conceal and a 'Dazzle' camouflage, which is designed to disrupt and confuse.

Information gathered at an exhibition titled Camouflage at the Imperial War Museum (IWM), London, in the summer of 2007 described the first camouflage. Military camouflage was first used by the French in 1914 and developed by artists who based their designs on the cubist style of painting. It was used to camouflage equipment and uniforms. These artists commanded their own title, camoufleurs (Camouflage exhibition at the Imperial war Museum in London (IWM).

Dazzle camouflage was developed for ships by Norman Wilkinson in 1917 and was designed to disrupt the viewer's perception of where exactly the object is (Newark, 2007). See Figure 3.12.

Figure 3.12 Example of Dazzle camouflage ship
(http://www.woostercollective.com/zebra-striped-camouflage.jpg)

The designs used on ships are comparable to the visual aesthetic of the Helmholtz Square Illusion described earlier in this chapter.

This 'Op Art' style of camouflage is discussed later in this chapter detailing its importance in Fashion and Art and Design.

3.4.3 *Camouflage in fashion and art*

In recent times camouflage has become evident in popular culture and can be seen in design, fashion and art. In an interview, James Taylor, who curated the

Camouflage exhibition at the Imperial War Museum, discussed the importance of dazzle

“ James expressed that it was the first camouflage to truly impact on visual culture.” He also said “Millions of people would have seen dazzle ships,... it was mainly the Merchant Shipping that it was applied to but also the Royal Navy, which is the symbol of Britain’s Empire. It’s the ‘swords and shield’ of Britain. If it is being put onto that it gives it a kind of gravitas that I think it might not otherwise of had” (Charrington, 2009)

Figure 3.13 – Jeff Koons ‘Guilty’ Yacht
(http://blogs-images.forbes.com/bethgreenfield/files/2011/07/00Q0gGvaOcd5f_360.jpg)

Jeff Koons used a combination of dazzle camoflauge and a Roy Liechtenstein style to design the exterior of the yacht The"Guilty", which is owned by art collector Dakis Joannou (Figure 3.13). This is a modern interpretation of the Dazzle camouflage that was used in the First World War. It is also a good example of how fashion designers cross boundaries and are influenced by art and illusion to create unexpected works in a different medium and environment from that expected (BallerRide, 2009).

A clear link to the visual aesthetic and illusionary effect of Dazzle can be seen in Havard Pedersen's work which was shown at the Master of Applied Arts (MAA) graduation show in visual arts from Emily Carr in Vancouver in 2009, see Figure 3.14. It shows a dual sided structure with a base that has been painted with a striped monochromatic optical pattern that displays dazzle properties. The effect of this is that the inside edges are initially harder to define and therefore the viewer is deceived by the pattern into questioning the real shape of the object (Emily Carr, 2009).

Figure 3.14 - Dazzle Study #04 MDF, Vinyl foil 65 x 55 x 35 cm 2009 (http://grad2009.ecuad.ca/images/maa_visual_arts/pedersen_havard03.jpg)

A similar effect was created by designer Annika Rimila who designed the Linjavitta dress for Marimekko, shown in Figure 3.15. The monochromatic optical pattern on the dress and the style of the dress are reminiscent of the Dazzle Camouflage that was promoted by Norman Wilkinson (Blechman, 2004).

Figure 3.15 – Annika Rimila stripy dress for Marimekko, 1967
(http://loosethreads.files.wordpress.com/2008/07/stripey_dress.jpg)

The Marimekko dress in Figure 3.15 is not the first of it's kind. An image that was shown at the Camouflage exhibition at the IWM portrayed a striking black and white image of Yvonne Gregory, who was the wife of photographer Bertram Park. The image, Figure 3.16, shows a Dazzle inspired dress with a dazzle inspired background. The styling of the model dictates the era and it can be easily deduced that it is the 1920's. The image displays a modern aesthetic and could be mistaken for the 1960's were it not for the styling. This early example of modern culture displays the shift in dress shapes and fashion aesthetics which started to become much looser in the 1920's from the previous very structured garments preceding this time as discussed in Chapter 1.

Figure 3.16 - Yvonne Gregory in dazzle camouflage dress 1919
(http://www.npgprints.com/lowres/38/main/25/39580.jpg)

“A print depicting Yvonne Gregory attending the DAZZLE BALL at Chelsea Arts Club in 1919. The image was originally taken for a London newspaper article, reporting on the ball and it’s dazzle theme. All attendees (including Yvonne) wore clothing inspired by Norman Wilkinsons’s camouflage designs, and Norman himself was asked to provide dazzle decorations” (Charrington 2009, p.16)

This evidence suggests that fashion and textile designers have referred to optical phenomena to distort the visual appearance of clothing. This can once again be seen in Figure 3.17, which shows a dress that claimed to be slimming in 1973 through the use of pattern.

Figure 3.17 – Slimming stripes dress from Golden Hands magazine, 1973
(Digital scan from Golden Hands magazine, 1973)

3.5 The use of shadow and shading to conceal

Although " Shadow originates in a local and relative deficiency of visible light" (Baxandall, 1995, P.1) shading gives the illusion of shadow, which can be created by synthetic means to achieve the same effect.

The use of line and shadow plays a major role in creating the illusion of depth and 3D. Leonardo da Vinci was significant in considering the importance of shading (Gregory et al 1995), and shading is a very important factor when considering a 3 dimensional aesthetic. In the natural world animals display shading and counter shading to distort their real shape to protect themselves from predators (Gregory et al, 1995).

Designs based on biomimicry, where concealment and deception are fundamental to survival, will contribute to this research and its practical work by hiding and accentuating the perceived female body shape.

3.6 Illusion in art and design

As described above, optical illusion can be created by manipulating line and shading to create cognitive dissonance. However, cognitive dissonance can also be created by manipulating colour. French physicist Michel-Eugene Chevreul first identified a general set of colour experiences in his influential model of colour theory (1839). He observed that two colours seen side-by-side will appear different than if they are solitary, and he called that the law of simultaneous contrast. The purple stripes in Figure 3.18 are the same colour even though they look different. This is because of their surrounding colours, black and grey. This type of visual effect can also emphasise the feeling of depth in a design and therefore has the quality of an optical illusion. A light colour will look even lighter when next to a dark colour. For example, when a yellow is next to its complementary colour, purple, it will look even more yellow. This phenomenon is discussed further in chapter 5 and 6.

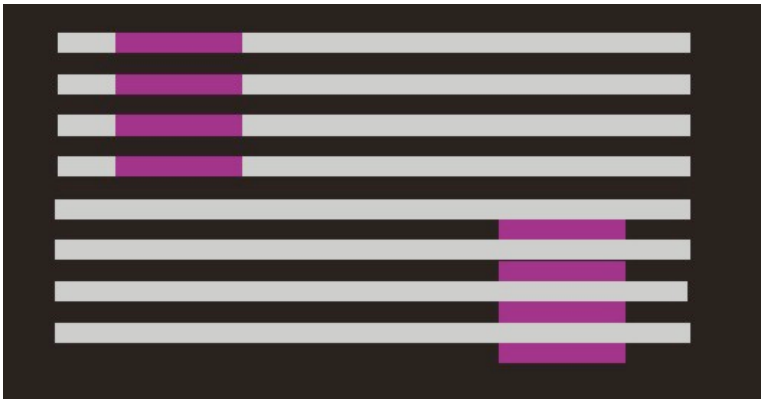

Figure 3.18 – Example of Chevreul's law of simultaneous contrast
(http://www.bigblackpig.com/painting/purple1.jpg)

Another illusion which informs this study is shown in Figure 3.19. This illusion, which was first described by Chevreul, is also described as the Mach effect or Mach banding. Each stripe appears to get lighter at the edge next to the darker stripe and lighter at the edge next to the lighter stripe. This is not actually the case as all the stripes are a solid colour. These stripes give the illusion of movement and a 3D quality. The effect is created by lateral inhibition, which highlights the change in luminance moving across the stripes (Latto, 1995).

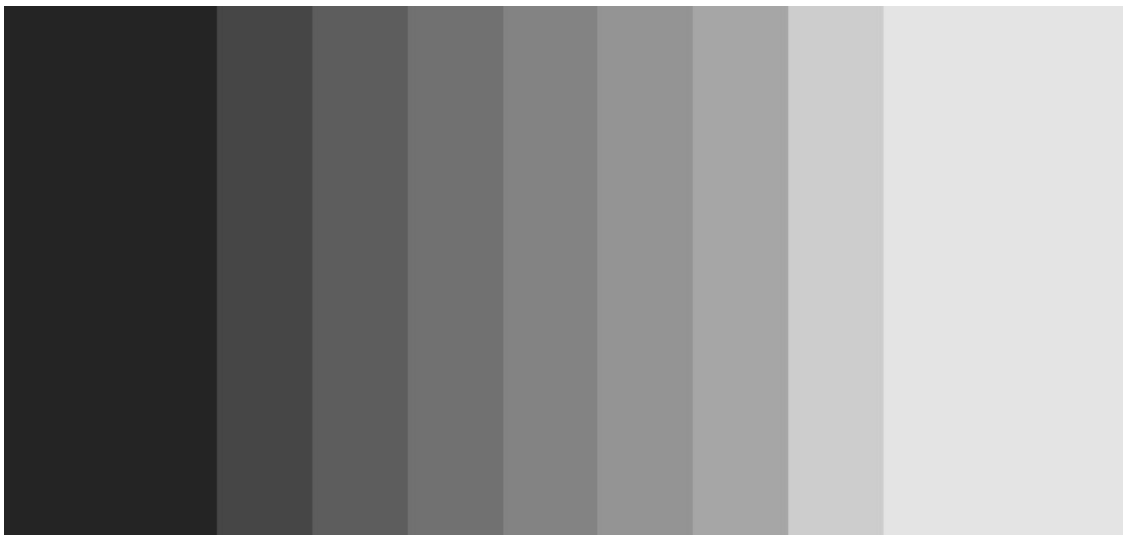

Figure 3.19 – Stylised impression by author of Chevreul's stripes (http://1.bp.blogspot.com/_8G6VfbRQs9c/TNYUNxCd0GI/AAAAAAAAA6Y/oOSSM6lyk3c/s640/Chevreulillusion.jpg)

3.6.1 *Victor Vasarely*

Vasarely who had been producing black and white optical paintings since the 1930s used techniques similar to Chevreul's. Figure 3.20 shows when there are many squares, an oblique light cross, like a large 'x', appears. This cross does not really exist. The illusion in Figure 3.20 has similarities with Chevreuls stripes seen in Figure 3.19 above. The effect seen in Figure 3.20 is an example of how Vasarely used techniques known as lateral inhibition and simultaneous brightness contrast to create effects that were optical (Latto, 1995).

Optical illusions created by painters like Vasarely led to the school of paintings known today as Op Art (Stangos, 1994). The intention of Op Art is to produce pattern which creates optical effects which disrupt visual processes and lead to cognitive dissonance. Op Art is important in this study as the manipulation of visual effects of Op Art for aesthetic purposes are similar to the effects which the designs in this research are intended to produce on the perception of the female form.

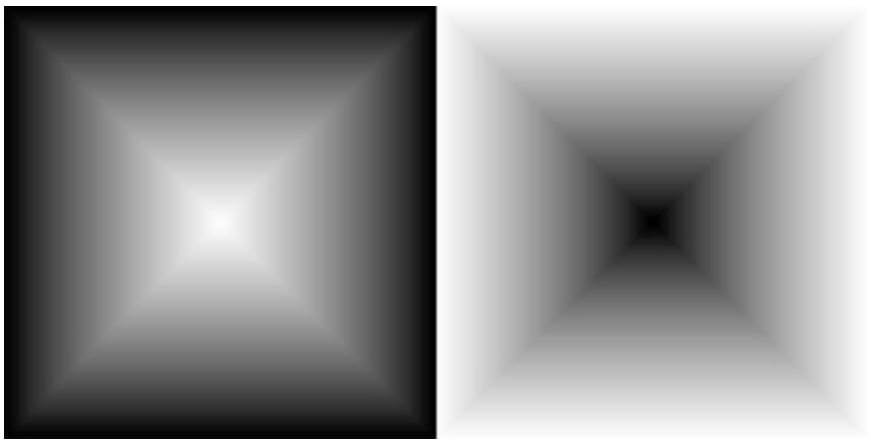

Figure 3.20 – Victor Vasarely, The pyramid effect 1966
(http://www.psy.ritsumei.ac.jp/~akitaoka/Vasarelyillusions.jpg)

The pyramid effect (also known as the Vasarely illusion) is a striking perceptual effect related to all phenomena involving lateral inhibition, similar to Chevreul's Mach Band. It has been incorporated into many Op Art paintings such as Arcturus II by Victor Vasarely (see Figure 3.21). The effect occurs when concentric squares of decreasing size and luminance are stacked on top of one another.

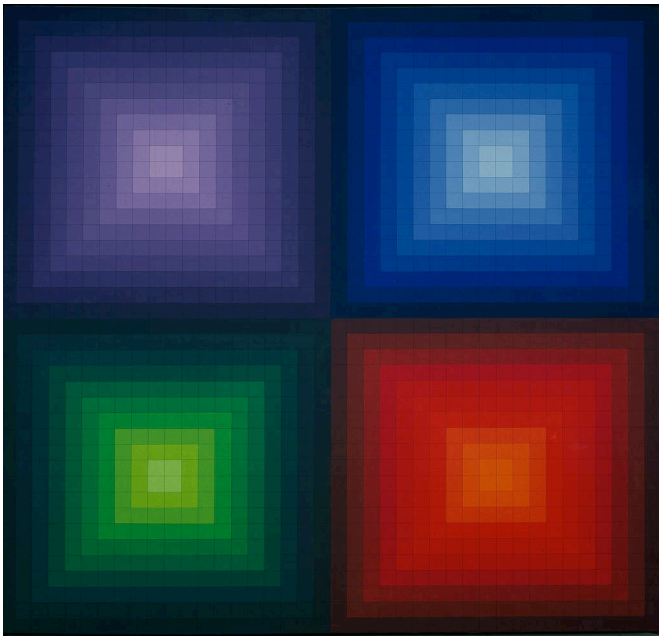

Figure 3.21 - Arcturus II by Victor Vasarely
(http://irea.files.wordpress.com/2008/11/arcturus-ii-1966.jpg)

Vasarely's work (see Figure 3.22) relating to line, echoes the optical illusions of Hering and Wundt (see Section 3.3). Carraher (1966) states "Distortions in a system of parallel lines create an illusion of three-dimensional topography".

(Carraher, 1966, page 39) This effect can be seen in the work of all three artists described in this chapter.

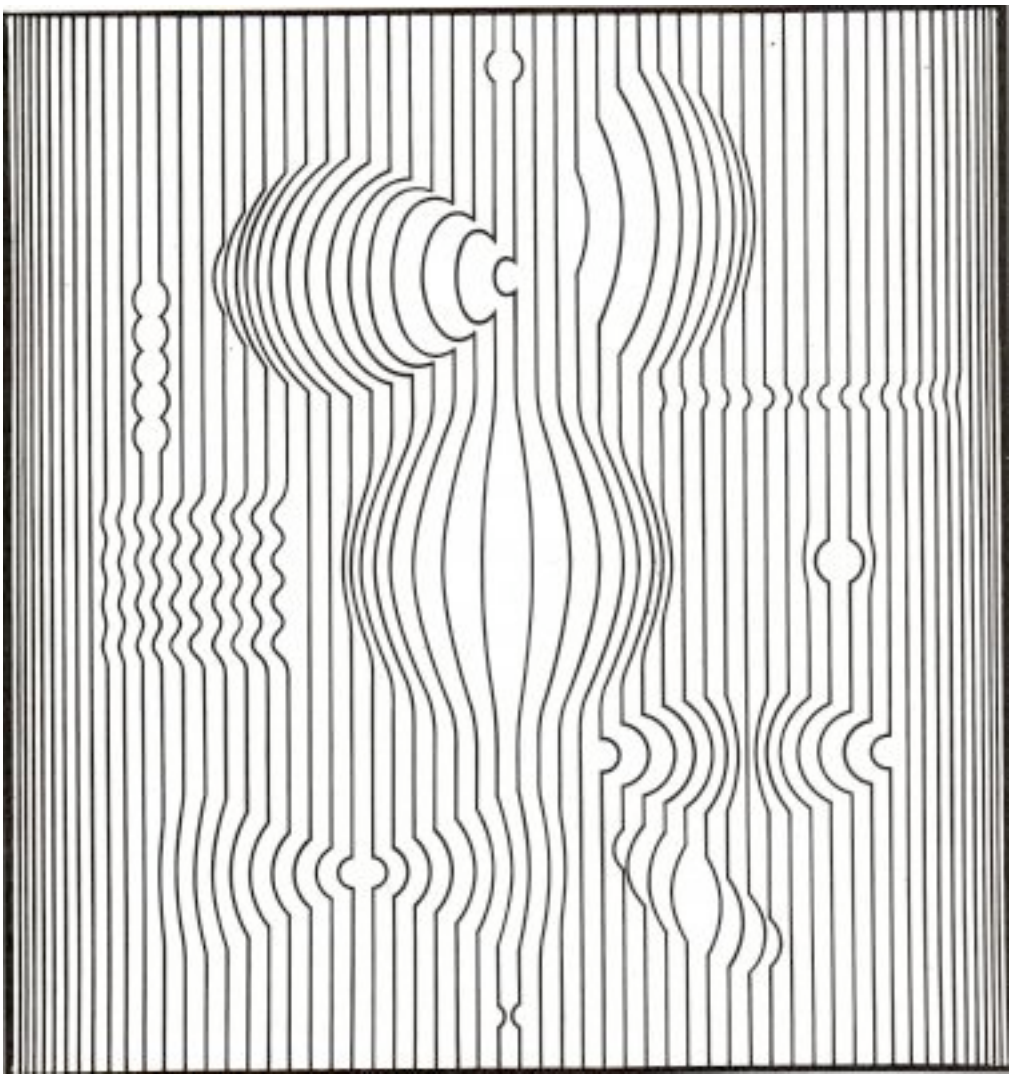

Figure 3.22 - Vasarely's Manipur 1952-60
(http://www.picturexl.com/albums/Fine_art/Paintings/Victor%20Vasarely/thumb_1952_60_Manipur.jpg

3.6.2 *Bridget Riley*

Like Vasarely, Riley produced work in simple lines that distorted and fooled the eye. In her pencil studies for 'Interrupted Circle' 1963 (see Figures 3.23 and 3.24) "A format of distorted concentric circles have been divided into three sections. Oblique straight lines connect the sections and suggest a series of ambiguous spatial separations" (Carraher, 1966, page 44)

Figure 3.23 - ‘Interrupted Circle’ 1963
(http://www.artvalue.com/photos/auction/0/39/39386/riley-bridget-1931-united-king-study-for-interrupted-circle-1430929.jpg)

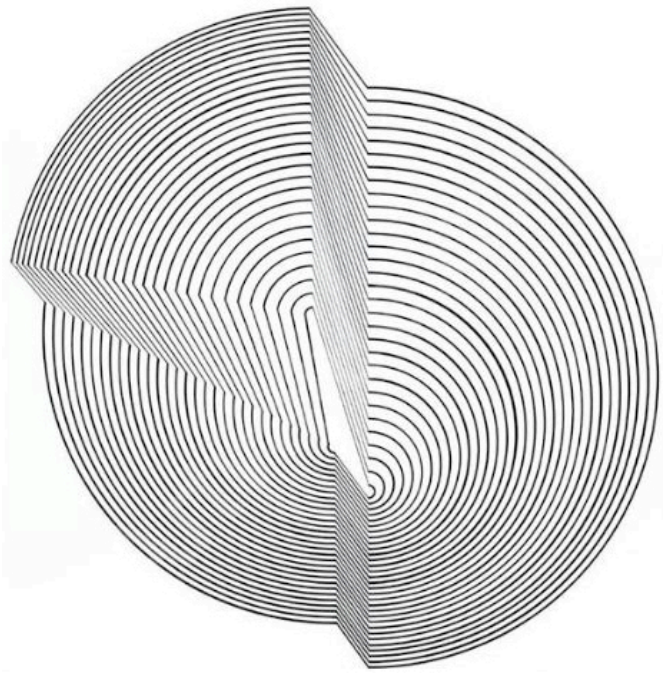

Figure 3.24 - ‘Interrupted Circle’ 1963
(http://www.artvalue.com/image.aspx?PHOTO_ID=1024029&width=500&height=500)

The simple monochromatic nature of Bridget Riley's optical work was an initial influence in the design process of this research.

In 1960 Riley started to work in black and white and her style of painting became much more optical, she evolved a style in which she explored the dynamic effects of optical phenomena. Riley's paintings create a physical and cognitive effect. Her work has the ability to interact with the viewer and creates an optical illusion through her use of line and pattern and undulating curves. She has said of her paintings ''the eye can travel over the surface in a way parallel to the way it moves over nature. It should feel caressed and soothed, experience frictions and ruptures, glide and drift'' (Tate, 2003). Her work demonstrates the essential quality of Op Art's ability to trick the eye (Riley, 2001). These illusions can be seen in Figures 3.25, 3.26 and 3.27.

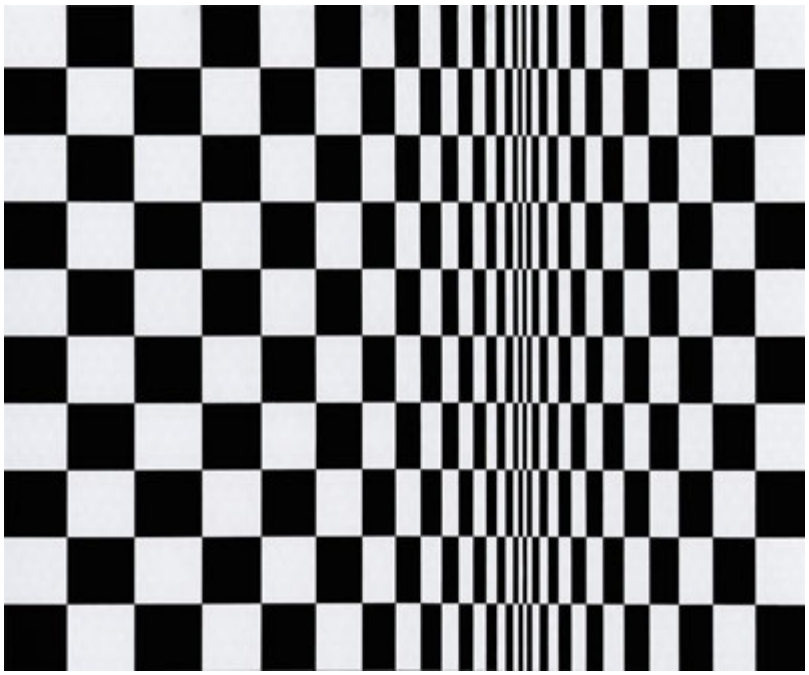

Figure 3.25 - Bridget Riley, Movement in Squares, 1961
(http://25.media.tumblr.com/tumblr_kwhaad3Uty1qa5h7no1_400.jpg)

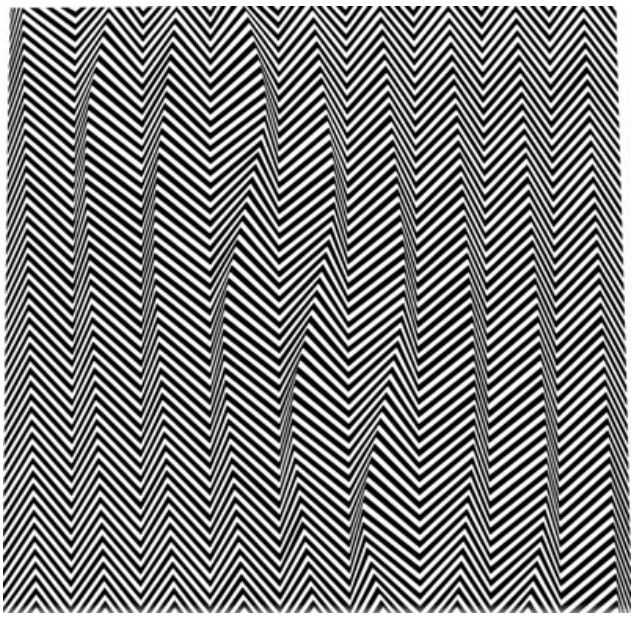

Figure 3.26 - Bridget Riley, Descending, 1965 (http://www.karinsanders.com/Bridget_Riley_Descending_1965_Emulsion_on_Hardboard_36x36.jpg)

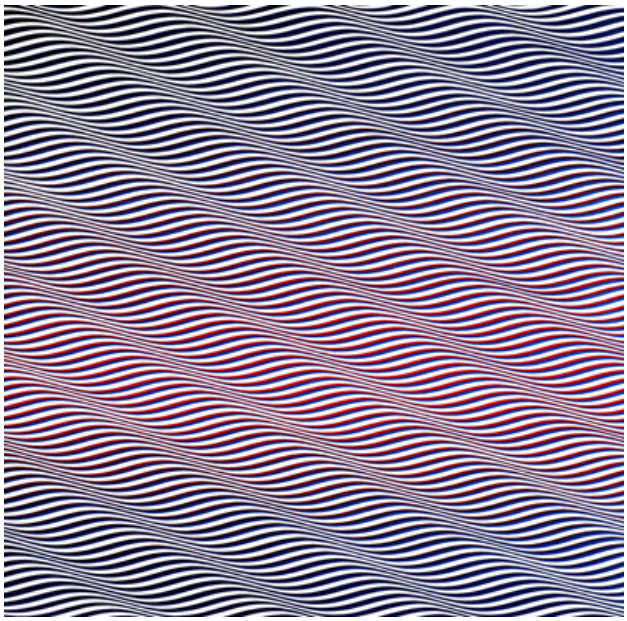

Figure 3.27 - Bridget Riley, Cataract 3, 1967 (http://venicebiennale.britishcouncil.org/media/5/riley_bridgetp996_cataract_3_resize_1.jpg)

Like Bridget Riley's black and white optical work, this research will culminate in a monochromatic design outcome . As Carraher (1966) asserts;

"the binary language for many of the painters and designers working with optical effects is black and white. Their invisible character provides a particularly dramatic vehicle for a wide range of perceptual experiences. A

direct connection exists between the purity of value contrasts and the clarity of form needed for maximum sensory impact. Black and white function optically somewhat like complementary colours because they present the eye with extremes of retinal stimulation." (Carraher, 1966, Page 11)

3.6.3 *Sarah Morris*

Sarah Morris, a contemporary optical artist has also provided inspiration for this research. Parallels can be drawn between Morris's paintings and the linear optical illusions of Herring and Wundt. The linear and graphic style of Sarah Morris's artwork is reminiscent of Mondrian and other modernist painters. Her stylised and very graphic representations of urban architecture display various vanishing points.

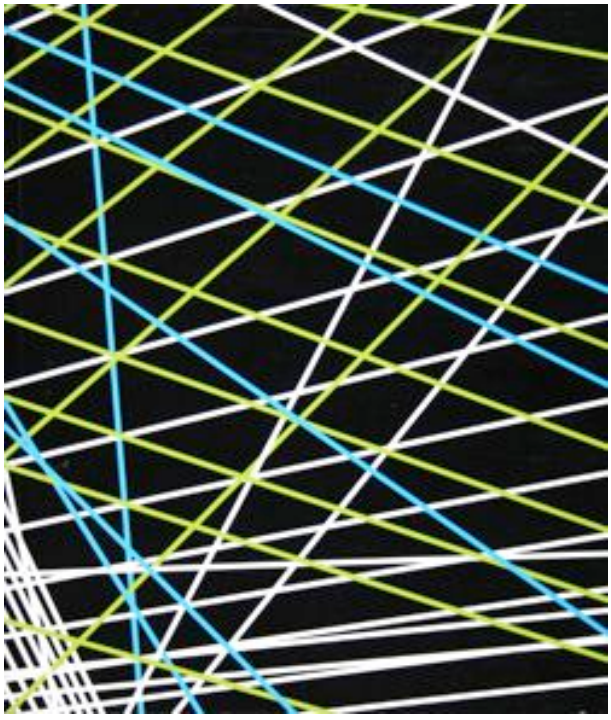

Figure 3.28 – Sarah Morris, Kunsthalle, Zürich, 2000
(http://www.whitecube.com/img/publications/83/f/sarah_morris_kunst.jpg)

Morris also displays a great understanding of perspective with her paintings as the crossing lines and displaced angles create depth. See Figures 3.28 and 3.29.

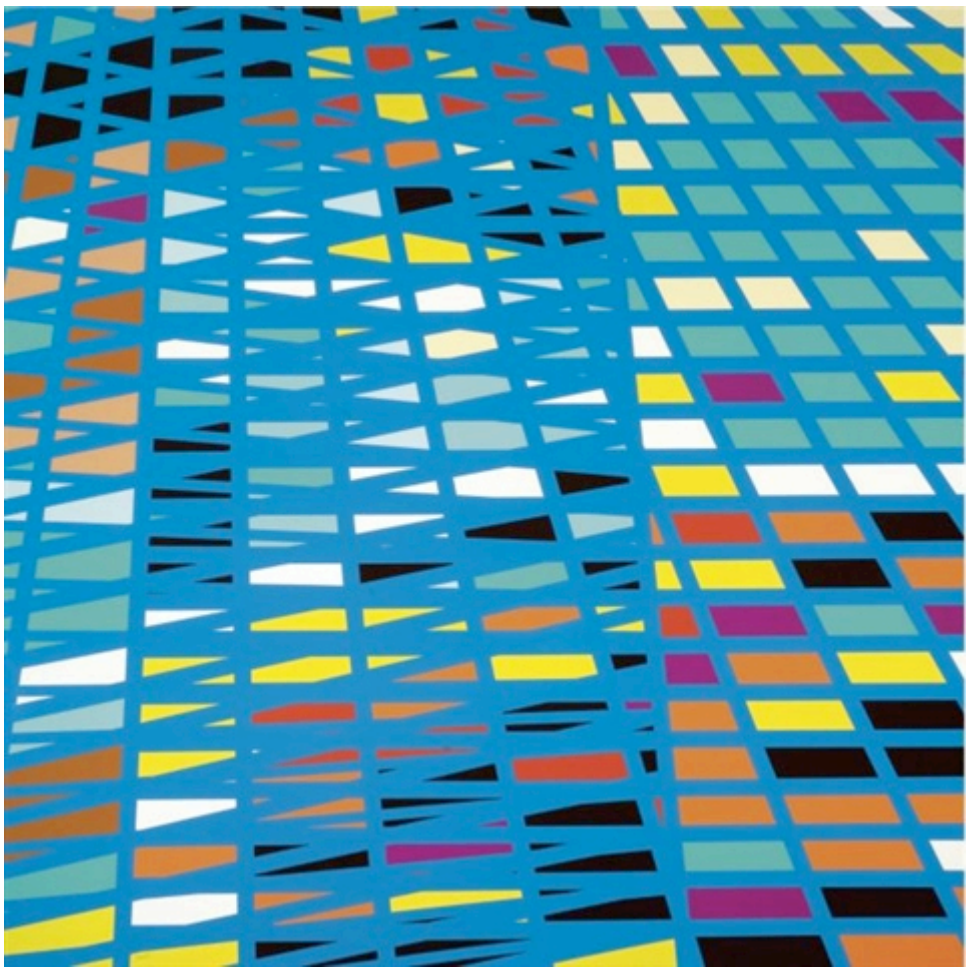

Figure 3.29 – Sarah Morris, Caesar's (Las Vegas), 2000
(http://images.artnet.com/WebServices/picture.aspx?date=20071115&catalog=126010&gallery=111558&lot=00445&filetype=2)

3.7 Summary

This chapter has provided a historical perspective on theoretical aspects of optical illusions and illusion in art and nature. Firstly psychological theories of illusion and perception, including the theories of Helmholtz, Herring and Wundt were described. The use of classifications such as: Physical Ambiguities, Physiological Ambiguities and Cognitive Ambiguities were discussed and described. The Cognitive Ambiguities such as the Hering and Wundt illusions are used in the design process of this research and are discussed again in Chapter 5 and displayed in the Digital Sketchbook. The Helmholtz Irradiation Illusion which is a Physical Ambiguity is also discussed again in this thesis in Chapter 5 as it too was used as an inspiration for experiments carried out in Chapter 4 and 5. The relevance of optical illusions, in a fashion context, is

described briefly by Thompson, who has looked at the Helmhotlz square illusion and discussed Helmholtz's views on ladies fashions Thompson (2007), his research is contradicted, however, by Imai (1982) and Sai et al (1998) sited in Taya and Miura (2005). These contradictions show that more research on the subject area is required to make a claim regarding which monochromatic optical patterns provoke which perceptions. Secondly camouflage used in a military context, nature and fashion and art was discussed. The main focus of this section looked at dazzle camouflage and the use of shading to conceal and distort the true edge of an object. These phenomena's are trialled and discussed further in experiments carried out in Chapter 5. Thirdly the use of shading in nature and art was briefly discussed. Finally illusion in art and design with particular reference to Op Art was described. Illusion and camouflage are important themes in this research and it is important that a wide variety of patterns have been discussed and illustrated. The choice to use Hering and Wundt as influences in the main designs used in the study is based on two factors. The first is the ease with which they could be replicated as printed fabric and the second was the seemingly simple nature of the designs. This decision made choices easier for the observers and the outcomes more easily interpreted, especially when the designs remained monochrome.

Chapter 4 traces the development of an experimental method influenced by the elements discussed in this Chapter. The Helmholtz Irradiation effect is used to create samples with an informed aesthetic. The final method chosen is detailed in Chapter 5. The illusions discussed in Chapter 5 are the Hering and Wundt illusions and attention is given to the effects of shading also.

3.8 References

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Chapter 4 – Experimental Development of Method

This chapter aims to describe and discuss how a test method for measuring size perceptions in this PhD were established. Three methods of testing will be discussed, Ranking, Paired Comparison and Rating. A new rating method named the Caltyre scale devised in the course of this study is explained fully in section 4.2.

An initial set of visual samples taken from unpublished work into fabric drape on women's bottoms carried out by a group of students led by Dr Lisa Macintyre (2005) informed the development of the final method which is described and discussed in Chapter 5. The samples, which show a rectangle in a mid grey colour on a background of dark blue, were the same as studio photographs used in the 2005 study. The visual samples used in MacIntyre's research provided a useful starting point for the development of further research in this similar field. Five tests using the original samples (see figure 4.1a, 4.1b and 4.1c) that were used in Macintyre's 2005 experiments were used to familiarise the researcher with the testing techniques and also to build a basis for creating an appropriate new method.

4.1 Developing test methods for visual assessment of size

An investigation into factors which influence human perception of size forms the core of this study. It was therefore important to develop a test method to measure this aspect of visual perception. The process described in this chapter resulted in the final method discussed in Chapter 5.

The purpose of these experiments was to determine:

- Whether observers could rank samples in order of length, width or area.
- How many observers were required to give reliable results.
- Whether a change in one dimension affected the way that a second dimension was perceived.

4.1.1 *Testing environment*

As light plays a major role in how we see and perceive what we are viewing, and as it comes from several different sources, it was important to specify and maintain one constant light source in any set of experiments. Standard illuminants such as D65 are often used. D65 is one of the standard illuminants defined by The International Commission on Illumination (CIE). A series of Illuminants called *D* series (one of which is D65) try to replicate natural sunlight. D65 corresponds roughly to a midday sun in Western / Northern Europe; hence it is used as an alternative to daylight illumination in standard test methods. D65 light was deemed the most appropriate light to use as this would be closest to natural light in the hemisphere in which the research took place, therefore giving as close a match to outdoor lighting in that location as possible.

The initial testing was undertaken in a controlled environment, or dedicated dark room with a light box which displayed D65 light to simulate European daylight. The experiments detailed in Chapter 4 were all performed in this environment.

4.1.2 *The observers*

To ensure easy access, observers were initially chosen from the staff and students attending The School of Textiles and Design. Observers were asked to sign a consent form before commencing experiments (refer to Appendix A) and a script was read to the observers to ensure consistency of wording for all tests performed (refer to Appendix B). Observers were asked to observe various images presented in the dark room where the light box was situated.

4.1.3 *Initial developments*

Twelve observers, chosen at random from research staff and students were invited to take part in the experiments. They were of mixed age and gender and had previous experience of performing visual assessments. A series of initial tests of ranking rectangles of different sizes were conducted prior to establishing test methods for perception of size (refer to Appendix C).

Figure 4.1a – samples used for rectangles of different length

Figure 4.1b – samples used for rectangles of different width

Figure 4.1c – samples used for rectangles of different area

Five mini experiments were conducted using 3 different sets of visual samples. Each set of samples concentrated on a separate element of the inner rectangle size: length, width or area. The 5 experiments were:

1. Rectangles of different length see Figure 4.1a – observers to rank from shortest to longest
2. Rectangles of different width see Figure 4.1b – observers to rank from narrowest to widest
3. Rectangles of different area (both width and length) see Figure 4.1c – observers to rank from smallest to biggest

4. Rectangles of different length see Figure 4.1a – observers to rank from narrowest to widest
5. Rectangles of different width see Figure 4.1b – observers to rank from shortest to longest

The 12 observers were each given the sets of visual samples shown in Figures 4.1a, 4.1b and 4.1c and were asked to rank the size of grey rectangles in order of increasing size from smallest to biggest (experiment 3), shortest to longest (experiments 1 and 5) or narrowest to widest (experiments 2 and 4). In order to ensure the reliability of the results each observer started with a different test, chosen at random. The random order of testing was used to minimise the effect that improvement of an observer's ability to perceive differences with practice would have on the results; therefore differences in results were averaged out (refer to Appendix D).

4.1.4 *Conclusions for initial developments – first 5 experiments*

The following conclusions can be drawn from the first 5 experiments:

- 2% differences in rectangle width and length were reliably perceived by a group of 12 observers using 5 samples and the ranking method.
- 4% differences in rectangle area were reliably perceived by a group of 12 observers.
- The mean of 12 observers did not show an obvious trend between increasing rectangle width and perceived rectangle length or increasing rectangle length and perceived rectangle width under these experimental conditions.

Therefore, in order to reliably measure real differences in size by ranking, 12 observers could be used. However, the ultimate aim of this research was;
"To create a conceptual design collection that demonstrates the perception of size caused by the optical effects of printed design on textiles." (See Aim 4 Page 14) Therefore to measure perceived differences in size where the 'difference' is created using optical illusion rather than real dimensional

difference required more observers, and/or a more dramatic illusional difference.

It was also concluded that after initial research into visual assessment and colour psychology the initial set of experiments contained several flaws for the successful continuation into the next step:

The discovery that a mid grey was preferable for a border colour rather than blue impacted on the reliability of the results. Grey would be a better border colour as this restores the eye back to equilibrium (Itten, 1992). Also the fact that the samples were being viewed in a light box that was painted in grey meant that with the samples that had the blue border, observers were judging the border and not the inner rectangle. This is discussed further in 4.2.1.

Another flaw in the initial experiments was the continuing issue concerned with accessing enough observers to make the results reliable. Therefore there was always the issue of too small a sample size.

Another observation was that although observers were asked to rank the samples from smallest to largest the method that they used was an informal paired comparison. Every observer picked up two samples and compared them to each other before putting them back in the light box in the order in which they believed was correct.

4.2 Evaluation of test methods for visual assessment of size

After the flaws were discovered in the initial experiments described in 4.1 a new set of samples were produced. It was decided to carry on with a set of experiments using 2D samples placed in a light box ('Verivide' CAC 150) observed by volunteers in a darkroom.

Three methods of visual assessment of size were used to develop the best method for measuring the perception of size. The Caltyre scale, which was devised for this series of experiments and is described in 4.2.1, and a visual sample set were used in a number of experiments where observers were asked

to rank, rate and compare the squares in order of perceived size. These three different methods of evaluation are described below:

Rating - the size of the internal square of the visual samples were compared/matched to the Caltyre scale.
Ranking - the visual samples were ranked in order from smallest internal square to biggest internal square.
Paired comparison - where the visual samples were compared in pairs and the observer asked to choose the biggest internal square.

The objectives for this part of the study were:

1. To establish the most reliable method of perception measurement.
2. To establish the optimum number of observers required for a reliable result.
3. To establish the limits of perception, that is how small a difference people can reliably perceive in mm.
4. To determine observer reliability on repeat measurements.

4.2.1 *Conception and creation of the Caltyre scale – creating the first set of visual samples*

The need to establish a method for the reliable grading of differences in perceived size of a printed object (square) led to the conception of 'The Caltyre Scale' shown in Figure 4.2. This is a new method of rating size that uses different sized inner squares, printed on a mid grey background of the consistent size of 40 cm x 40 cm. The Caltyre scale is a similar concept to the Greyscale (see Figure 4.3) where comparisons of sameness are made by matching and rating a test specimen's colour to the colour on the grey scale. In the case of the Caltyre scale the size of the inner square would be matched to the scale of a square, therefore giving an indication of the observers' perception of size differences.

Figure 4.2 – Caltyre scale, a scale for the measurement of the perception of size

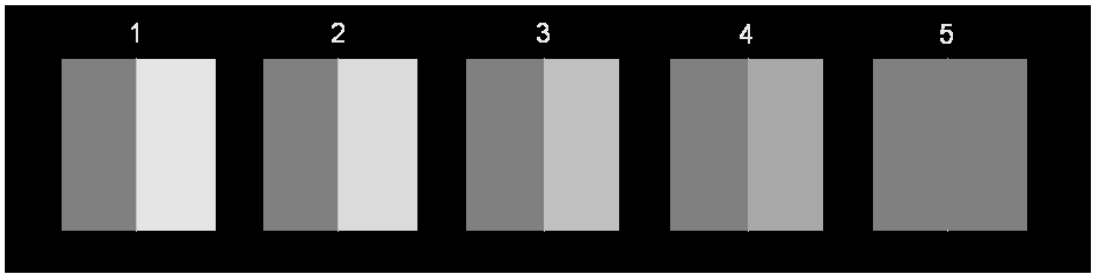


Figure 4.3 – Greyscale reference card, for visual measurement of closest grey value

(Stylised impression of grey scale BS EN 20105 AO2)

Square prints were used as they give minimum sensation debate of colour or shade difference. This can also be applied to differences in size. Only a square will allow symmetry and ease of use when samples require to be compared. The decision to use squares has also been heavily influenced by Johannes Itten's use of these in his colour studies (Itten, 1992) and the fact that squares are used for both the BS grey scale and AATCC comparison and rating methods (British Standard Testing Document).

The external dimensions of the Caltyre scale and visual samples were 40 cm X 40 cm. The lengths and widths of the internal squares ranged from 19.5 cm up to 20.5 cm increasing at 0.1 cm intervals see Figure 4.2. These sizes and proportions were selected for the following reasons:

- The external dimensions of AATCC replicas in the crease test are 380 mm x 380 mm
- Three 40 cm samples will sit in the light box side by side thus recreating other visual assessment methods as used by the AATCC
- The internal dimensions of the square print were half those of the external square as this proportion is used in the typical BS Greyscale and Itten colour samples and is intended to focus the observer's eye on the internal print and not the dimensions of the margin (Itten, 1992).
- A border was used to focus the observer's eye on the internal square

The investigation into the perception of size was started with black internal squares on a grey background (version 1). The combination of black on grey squares was based on the visual appearance of the grey Scale. The basis for

black on grey backgrounds is based on theories discussed by Itten. Itten describes the relationship between black and white as having size distorting properties. Different optical effects can be produced depending on the background colour. For example; a white square on a black background looks larger than a black square on a white background. In this instance the black appears to contract and looks smaller, whereas the white square will overflow and appear larger (Itten, 1992).

Combining monochromes can have visual effects. Two grey squares with equal value will look different depending on the background or adjacent colour/ monochrome. Therefore the grey selected for this study was Munsell N5 grey as this was the same as the standard colour for the interior of the light box cabinet and gave the illusion of no background colour. The other significant reason for using a mid grey as a border round the different sized black squares is because a mid grey will restore an equilibrium back to the eyes after they have looked at black, white or colour. This means that the eyes when observing will not be influenced by a preceding image or colour (Itten, 1992).

4.2.2 *Printing the correct grey for the Caltyre scale and visual samples*

The correct grey was produced to match the Munsell N5 paint used in the light box with the printed grey background on the Caltyre scale and visual samples. The Caltyre (perception) scale and visual samples were created in Photoshop and printed on Epson enhanced matt paper. The Munsell N5 grey was matched through a visual process of elimination using the following method:

1. A piece of white card was painted with 2 layers of Munsell N5 paint.
2. The painted card was scanned into Photoshop, but the scanned grey was too dark and too far removed from the Munsell N5 painted card.
3. Grey swatches were generated using Adobe Photoshop 7 and were printed using Epson Ink cartridges onto EPSON Enhanced Matte Paper using an Epson Colour Stylus pro 7600 printer (ink jet printer).
4. Photoshop was used to manually generate 26 different grey square swatches (10 cm x 10 cm) on screen by changing the redness, greenness and blueness (RGB) values. These were printed onto white

card (printed greys) using the printer that would be used to print all visual samples and Caltyre scales for this experiment.

5. The painted card was compared to the 26 printed greys in the light box under D65 light to identify the ‘closest grey’, with a printed grey being accepted when it was within half a grey scale rating of Munsell N5.
6. The first batch of 26 greys were rejected as they were not within half a grey scale rating of Munsell N5.
7. The RGB values of the ‘closest grey’ were changed slightly to produce a further 12 printed grey swatches.
8. The process of identifying the ‘closest grey’ and manipulating it to produce further printed grey swatches was repeated a further 10 times until the researcher was satisfied that a visual match for the Munsell N5 painted card had been found.
9. The chosen grey was then verified by 3 independent observers and a RGB value of R-110, G-102, and B-96 was chosen to be the closest match.

4.2.3 *Printing the Caltyre scale and visual samples*

When developing test methods for the Caltyre scale and the visual samples it was unknown at that stage how big or small a difference would be perceivable. The following sizes were the initial test sizes, which could be adjusted after examination of initial results. The Caltyre scale and visual samples had black squares printed on grey backgrounds, with the Red, Green and Blue values detailed in section 4.2.3, 7 – no 9, with the following internal dimensions for each set:

- 4 mm difference- 19.2, 19.6, 20.0, 20.4 and 20.8 mm squares; referenced (BSoG-19.2, BSoG-19.6, BSoG-20, BSoG-20.4 and BSoG-20.8)
- mm difference- 19.4, 19.7, 20.0, 20.3 and 20.6 mm squares; referenced (BSoG-19.4, BSoG-19.7, BSoG-20, BSoG-20.3 and BSoG-20.6)
- mm difference- 19.6, 19.8, 20.0, 20.2 and 20.4 mm squares; referenced (BSoG-19.6, BSoG-19.8, BSoG-20, BSoG-20.2 and BSoG-20.4)

- 1 mm difference- 19.8, 19.9, 20.0, 20.1 and 20.2 mm squares; referenced (BSoG-19.8, BSoG-19.9, BSoG-20, BSoG-20.1 and BSoG-20.2)

Two full sets of visual samples were produced on a grey background. One set became the Caltyre scale (a rating scale similar to the BS grey scale), and the other the 'Visual Sample Set' (VSS) to evaluate the reliability and usefulness of different test methods. These were used in all 3 experiments.

The length and width dimensions of the visual samples and Caltyre scale were measured to double check that they were all the correct size. The size proved simple to maintain consistently, however initial problems with the printer suggested that the grey may be difficult to keep consistent. Each batch of squares printed saw the grey vary from the Munsell N5 and was also printing with visible stripes. This kind of variation was unacceptable as consistency is vital. The worst samples were reprinted to an acceptable standard.

4.2.4 *Evaluating the perceived difference in size of internal squares of visual samples*

All of the visual samples in the sample set were given reference numbers according to visual combination and size of Inner Square, for example reference BSoG-19.5 corresponded to a 19.5 cm x 19.5 cm Black Square on Grey background. All the reference numbers were on the reverse of the Visual Samples and the Caltyre Scale hidden from the observers, being for the test controller's use only.

Four different sets of the Caltyre scale were produced. The first with 1 mm differences between internal square dimensions, the second with 2 mm differences between internal square dimensions, the third with 3 mm differences between internal square dimensions and the fourth with 4 mm differences between internal square dimensions.

All Caltyre scale samples were referenced similarly for the test controller's reference only. The Caltyre scales were marked with different coloured dots on

the bottom left hand corner to signify the difference between 4 mm (Red), 3 mm (Green), 2 mm (Yellow) and 1 mm (Blue) differences for easy reference.

Initial tests were performed with 5 observers with plans to scale up the experiment if initial results were positive. All observers were assigned a reference number for the duration of the experiments. i.e. OB1, OB2, OB3… and so on. Each observer was asked to perform the experiments in a different random order.

Paired comparison, ranking and rating were performed in a darkened room within a Light box cabinet. The interior of the cabinet was Munsell N5 grey. The light used was D65 to simulate daylight in Europe.

4.2.5 *Ranking method*

The method of Ranking was also used using a set of Visual samples identical to the Caltyre scale as described in 4.2. Different sized internal squares are ranked from smallest to biggest until there is an order present of smallest on the left and biggest on the right. Individual responses were recorded where the internal square identified as 'smallest' was placed on the left, then the next biggest was on the right of the smallest, then the midsized square was next on the right, then the second biggest was next on the right and the biggest was after that on the far right hand side. All samples were viewed and ranked upright and level with the observers eyes. The results of all observations were recorded in Excel (see Appendix E).

4.2.6 *Paired comparison method*

This method of evaluation was used to determine which out of 2 visual samples the observer found the biggest. The observer was shown 2 visual samples exactly the same as the square design of the Caltyre scale described in section 4.2.1, and asked to point to the sample which had the bigger internal black square. All samples were viewed and ranked upright and level with the observers eyes. The results of all observations were recorded in Excel (see Appendix F).

4.2.7 *Rating with the Caltyre scale*

This method of evaluation was used to determine whether observers could match Caltyre scale samples with visual samples in a similar way to the grey scale discussed previously in this chapter. The observer was shown 1 visual sample in the light box and asked to choose a Caltyre scale sample whose inner square matched the visual sample and place it to the left or right of the sample in the light box depending on whether it appeared bigger or smaller. All samples were viewed and ranked upright and level with the observers eyes. The results of all observations were recorded in Excel (see Appendix G).

4.2.8 *Evaluation of ranking method*

Each observer was given a set of 5 visual samples with differences of 4 mm in the dimensions of the internal square. The internal squares measured 19.2 cm x 19.2 cm up to 20.8 cm x 20.8 cm, referenced BSoG-19.2, BSoG-19.6, BSoG-20, BSoG-20.4 and BSoG-20.8, See Figure 4.9.

The following scripted question was used: 'Please take these samples and place them in order of the smallest black square increasing to the largest black square. Please place them from left to right. Thank you'.

All samples were viewed and ranked upright and level with the observers eyes. The results of all observations were recorded in Excel, (see Appendix E).
The above procedure was repeated with the following visual sample sets:

- mm difference- 19.4, 19.7, 20.0, 20.3 and 20.6 mm; referenced (BSoG-19.4, BSoG-19.7, BSoG-20, BSoG-20.3 and BSoG-20.6), see Figure 4.10.
- mm difference- 19.6, 19.8, 20.0, 20.2 and 20.4 mm; referenced (BSoG-19.6, BSoG-19.8, BSoG-20, BSoG-20.2 and BSoG-20.4), see Figure 4.11.
- 1 mm difference- 19.8, 19.9, 20.0, 20.1 and 20.2 mm; referenced (BSoG-19.8, BSoG-19.9, BSoG-20, BSoG-20.1 and BSoG-20.2), see Figure 4.12.

Each observer was given the different sized sets randomly, so observer 1 may have rated 3 mm then 2 mm then 4 mm then 1 mm, however, observer 2 may have rated 4 mm then 1 mm then 3 mm then 2 mm and so on.

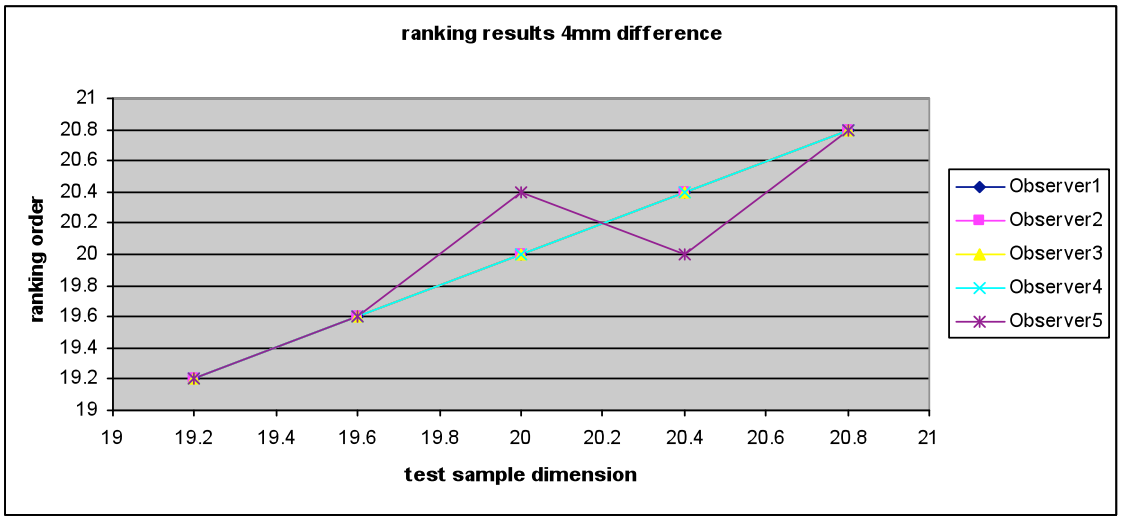


Figure 4.9 – observers ranking of Visual Samples with a 4 mm difference

Figure 4.9 shows that 4 observers were able to rank the visual samples in perfect order from smallest to biggest. 1 observer transposed 2 samples. Therefore these observers were able to rank a 4 mm difference effectively.

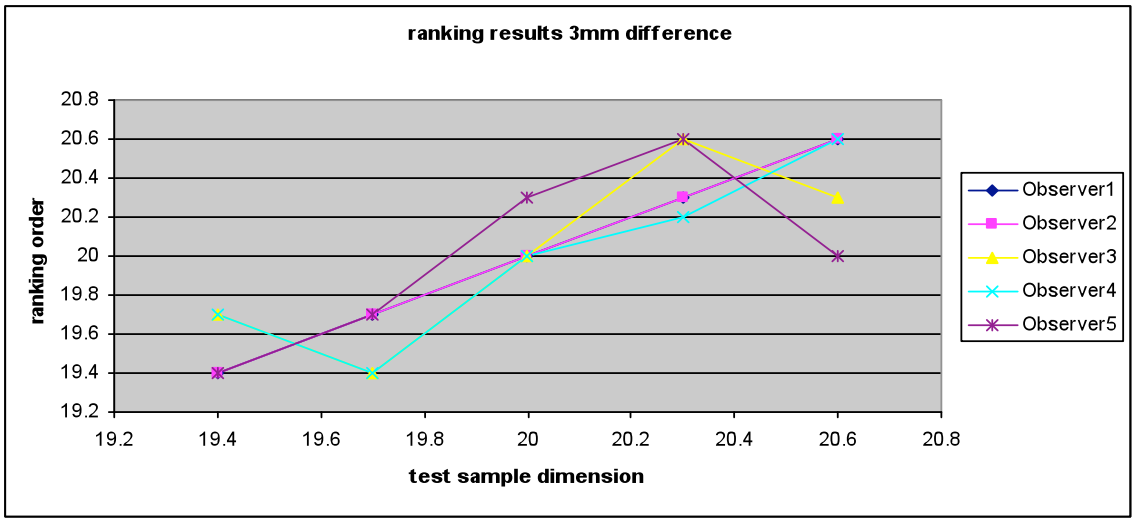


Figure 4.10 - observers ranking of Visual Samples with a 3 mm difference

Figure 4.10 shows that 2 observers were able to rank the visual samples in perfect order from smallest to biggest. 3 observers had more difficulty perceiving 3 mm differences in this test.

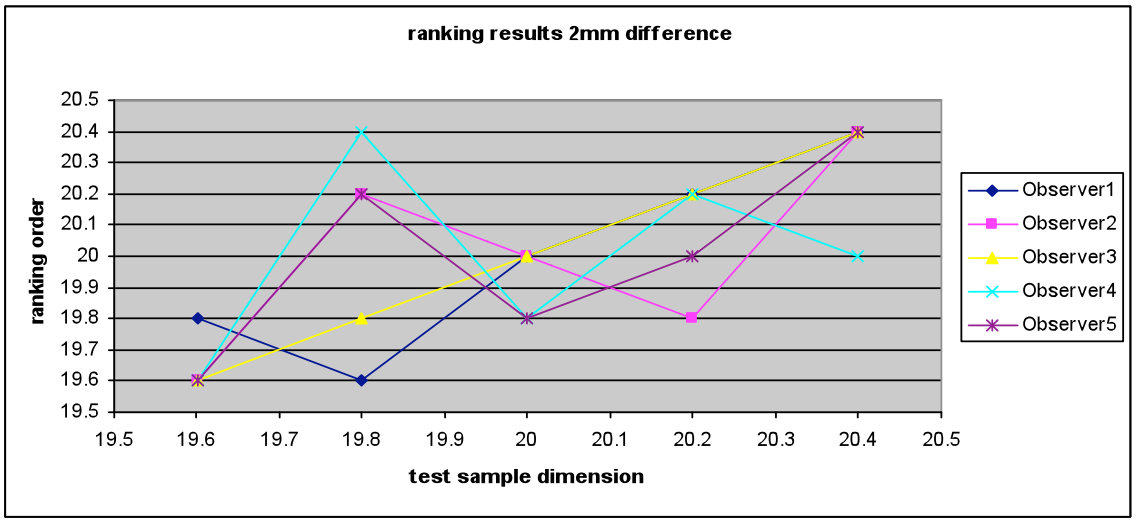


Figure 4.11 - observers ranking of Visual Samples with a 2 mm difference

Figure 4.11 shows that observer 3 was the only observer to rank a 2 mm difference perfectly. Observer 1 transposed only 2 samples indicating that they experienced slight difficulty in ranking 2 mm differences. However the remaining 3 observers were unable to reliably perceive a 2 mm difference using this test method.

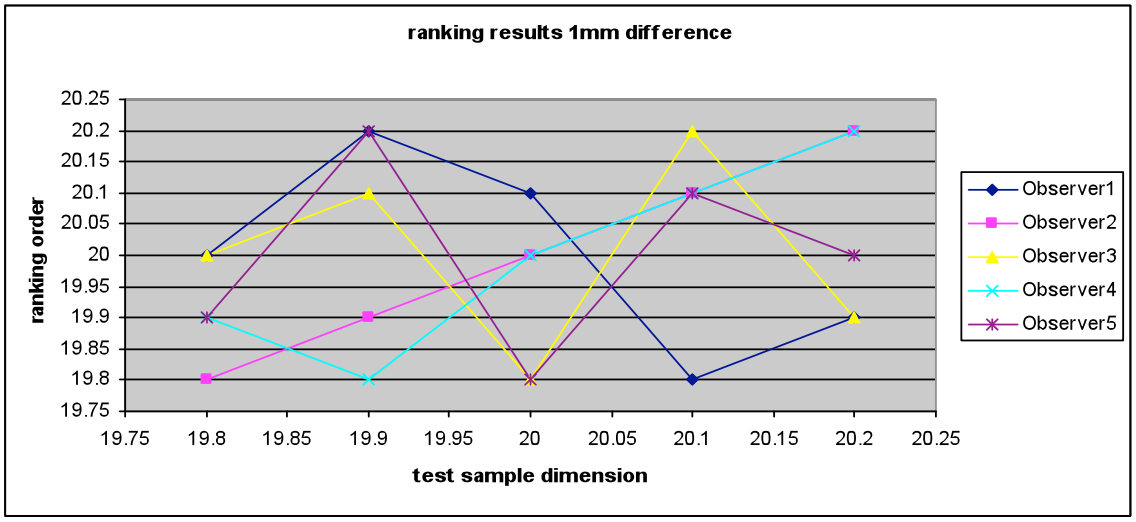


Figure 4.12 - observers ranking of Visual Samples with a 1 mm difference

Figure 4.12 show's that observer 2 was the only observer to rank a 1 mm difference perfectly. Observer 4 transposed only 2 samples indicating that they experienced slight difficulty in ranking 1 mm differences. However the remaining 3 observers were unable to reliably perceive a 1 mm difference using this test method. See Appendix E for full results.

4.2.9 *Evaluation of paired comparison method*

A total of 4 paired comparison experiments were undertaken with 5 observers. These tests were presented in random order. One of these tests measured the observer's ability to perceive a difference of 4 mm in the internal dimensions of a set of 5 visual samples as described below. The remaining tests measured observers' ability to perceive a difference of 3, 2 or 1 mm in the samples' internal dimensions.

To perceive a 4 mm difference observers were shown 2 samples at a time; these were randomly selected from BSoG-19.2, BSoG-19.6, BSoG-20, BSoG-20.4 and BSoG-20.8. The samples were placed side by side in the middle of the light box stand by the test controller (samples were randomly placed so that each sample appeared on both left and right during the experiment). During the experiment each sample was paired with every other sample in the set (so that BSoG-19.6 was compared to BSoG-19.8, BSoG-20, BSoG-20.2 and BSoG-20.4, etc.) and the observer was asked "please point to the sample in which the inner square looks bigger". The test controller noted the reference code of the sample that had been selected as bigger in the paired comparison grid (see Figure 4.13), removed the samples and placed the next pair on the light box stand. The results from each observer were tallied manually and recorded in Microsoft Excel. This method was repeated for samples with 3 mm, 2 mm and 1 mm differences see Section 4.2.8 for lists of samples included in these sets.

OBSERVER CODE -

PC OBSERVATION 1 - DATE -

Paired Comparison test grids

Black Squares on Grey samples (4 mm difference)

					number of times sample was 'bigger'
19.2 / 19.6	19.2 /20	19.2 / 20.4	19.2 / 20.8	19.2	
	19.6 / 20	19.6 / 20.4	19.6 / 20.8	19.6	
		20 / 20.4	20 / 20.8	20	
			20.4 / 20.8	20.4	
				20.8	

Figure 4.13 – Example of paired comparison grid for 4 mm difference

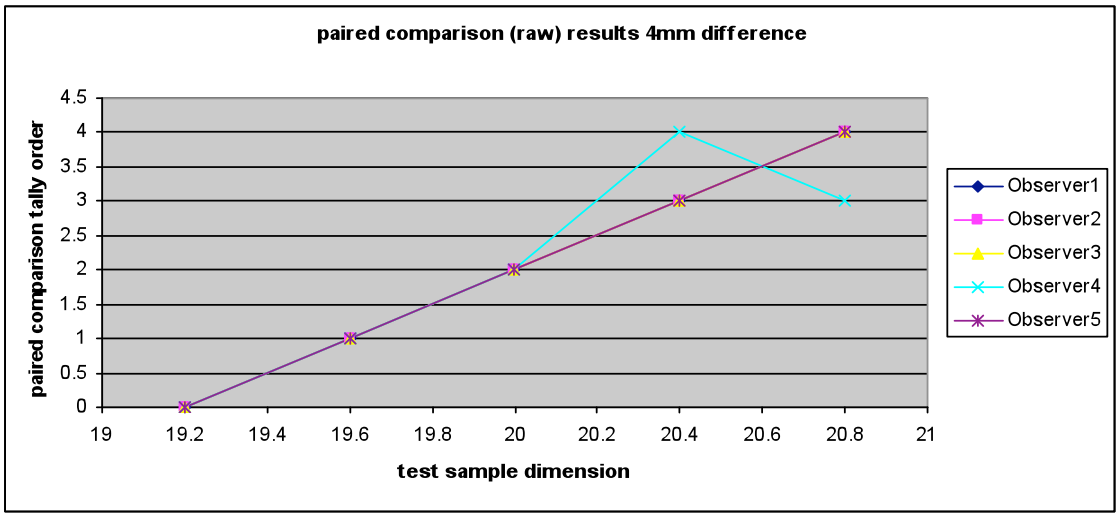


Figure 4.14 - observers paired comparison of Visual Samples with a 4 mm difference

Figure 4.14 shows that 4 observers were able to compare 2 visual samples and perfectly determine which sample was 4 mm bigger. 1 observer failed to identify the correct sample on 2 occasions. Therefore at a 4 mm difference these observers were able to determine the bigger of 2 visual samples effectively.

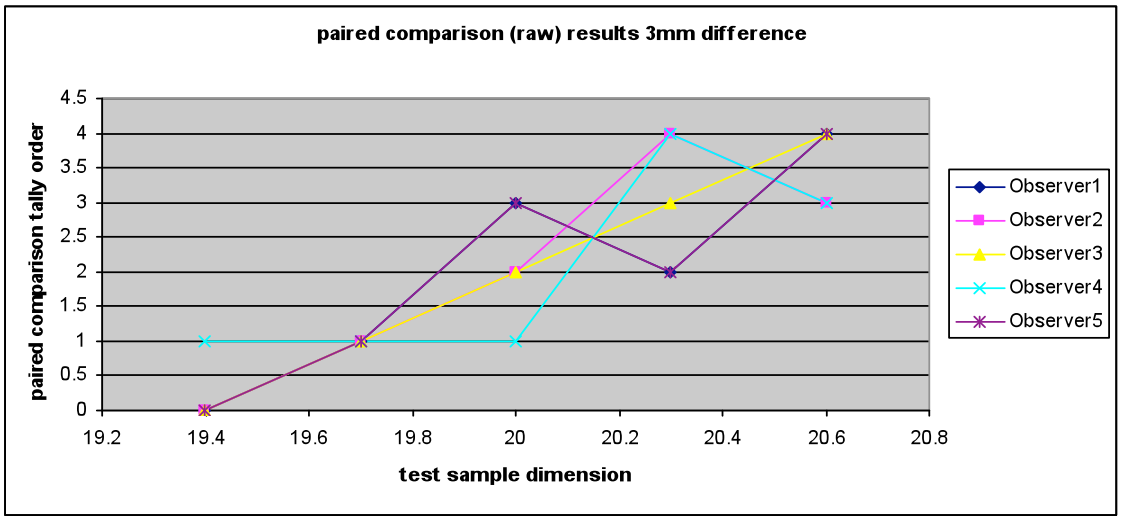


Figure 4.15 - observers paired comparison of Visual Samples with a 3 mm difference

Figure 4.15 shows that observer 3 was able to compare 2 visual samples and perfectly determine which sample was 3 mm bigger. Observer 2 failed to

identify the correct sample on 2 occasions. The remaining 3 observers were unable to perceive a 3 mm difference with any consistency.

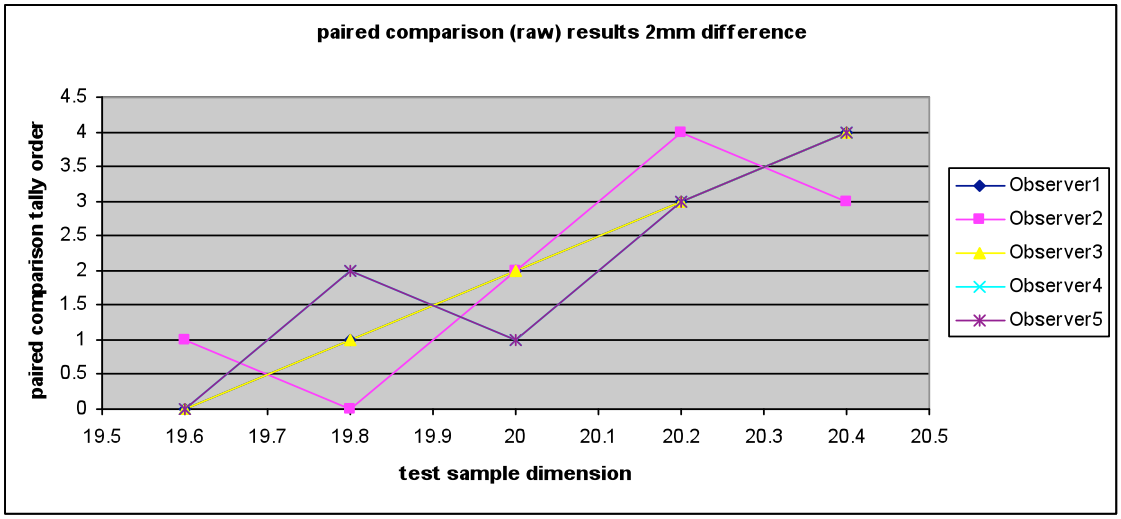


Figure 4.16 - observers paired comparison of Visual Samples with a 2 mm difference

Figure 4.16 shows that 3 observers were able to compare 2 visual samples and perfectly determine which sample was 2 mm bigger. Observer 2 failed to identify the correct sample on 2 occasions. The remaining 3 observers were unable to perceive a 3 mm difference with any consistency.

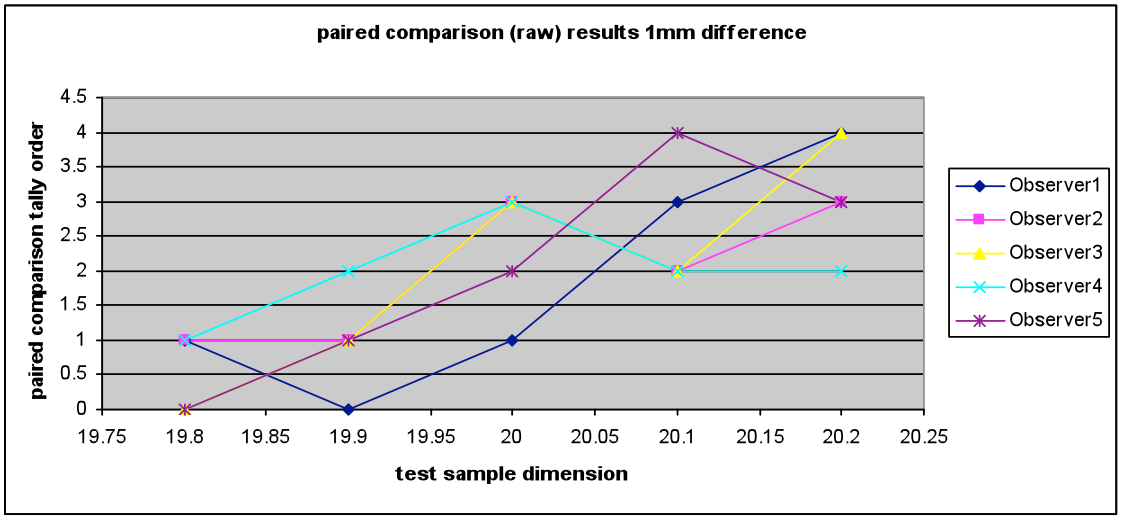


Figure 4.17 - observers paired comparison of Visual Samples with a 1 mm difference

Figure 4.17 shows that all 5 observers were unable to compare 2 visual samples and perfectly determine which sample was 1 mm bigger. Observer 5 identified the correct sample on 3 occasions. The remaining 4 observers were unable to perceive a 1 mm difference with any consistency. See Appendix F for full results.

4.2.10 *Evaluation of 'The Caltyre Scale' version 1*

Rating using Black Samples on Grey background Caltyre scale. The prototype Caltyre scale consisted of 11 standards with internal square dimensions ranging from 19.5 cm to 20.5 cm increasing in 1 mm increments. However, in these initial experiments 4 limited Caltyre scales with only 7 standards each were used to test observers' ability to perceive a difference of 4, 3, 2 and 1 mm respectively (to match with the ranking and paired comparison tests described in Sections 4.2.8 and 4.2.9).

The numbered Caltyre Scale Standards (CSS - referenced CSS-18.8 to CSS-21.2) were placed in order of increasing inner square dimension on a bench next to the light cabinet. The test controller placed a visual sample (randomly selected from BSoG-19.2, BSoG-19.6, BSoG-20, BSoG-20.4 and BSoG-20.8) in the centre of the light box stand. Observers were then asked to find the Caltyre Scale Standard (CSS) whose inner square most closely matched the size of the Visual Sample's inner square. Observers were instructed to place the smallest CSS (19.2) on the left of the Visual sample and the biggest CSS (20.8) on the right of the Visual sample. Once the observer had determined which CSS extreme (19.2 or 20.8) was furthest in size from the test sample they were asked to remove it and replace with the central CSS (20). They then sought to match the size of the test sample's inner square to the corresponding CSS by a process of elimination. The observer was asked to place the CSS on both sides of the test sample to confirm their choice before their result was recorded. This process was repeated with the remaining 4 test samples, placed in random order in the centre of the light box stand by the test controller. Results were recorded in a grid similar to that shown in Figure 13 and were then entered to Microsoft Excel for further analysis. This process was repeated

for the 3 mm, 2 mm and 1 mm sets (see Figures 4.19, 4.20 and 4.21) in random order.

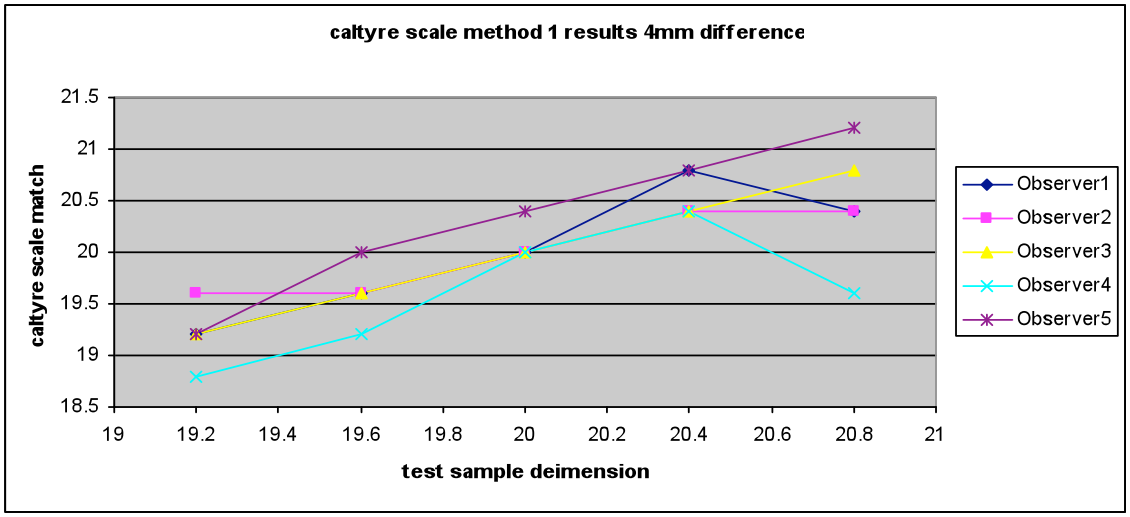


Figure 4.18 – Visual Samples matched to Caltyre Scale at a 4 mm difference

Figure 4.18 shows that 1 observer was able to match the visual samples to the Caltyre Scale perfectly for all 4 mm samples. 2 observers matched 3 samples perfectly and 1 observer matched 2 samples perfectly and the remaining observer only matched 1 Visual Sample perfectly, however all but one observer was no more than 4 mm out when they matched the wrong sample. Therefore these observers were able to match 4 mm difference samples with some efficiency.

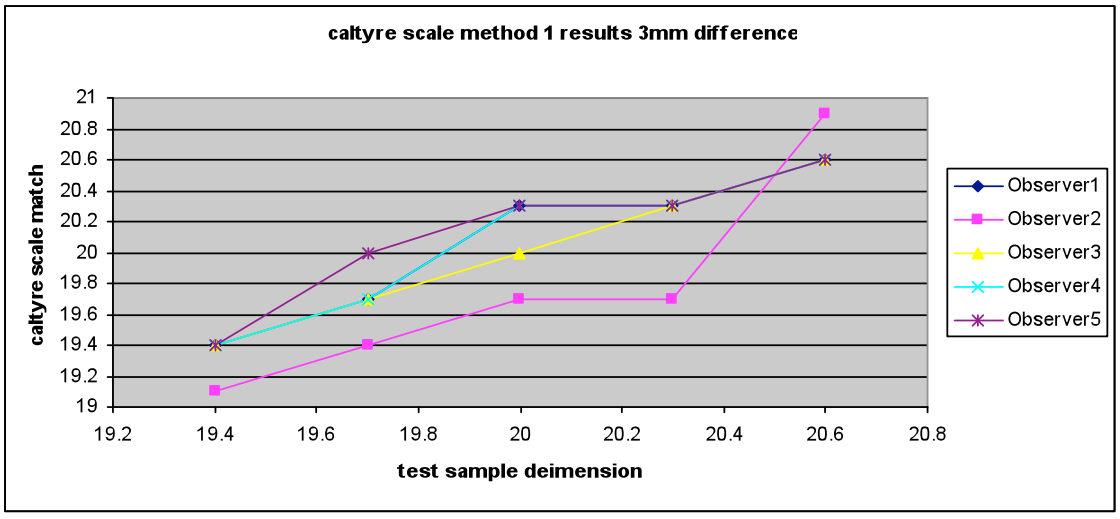


Figure 4.19 - Visual Samples matched to Caltyre Scale at a 3 mm difference

Figure 4.19 shows that 1 observer was able to match the visual samples to the Caltyre Scale perfectly for all 3 mm samples. 2 observers matched all but 1 sample perfectly. 1 observer matched 3 samples perfectly and 1 observer failed to match any samples, however all but one observer was no more than 3 mm out when they matched the wrong sample. Therefore these observers were able to match 3 mm difference samples with a little difficulty.

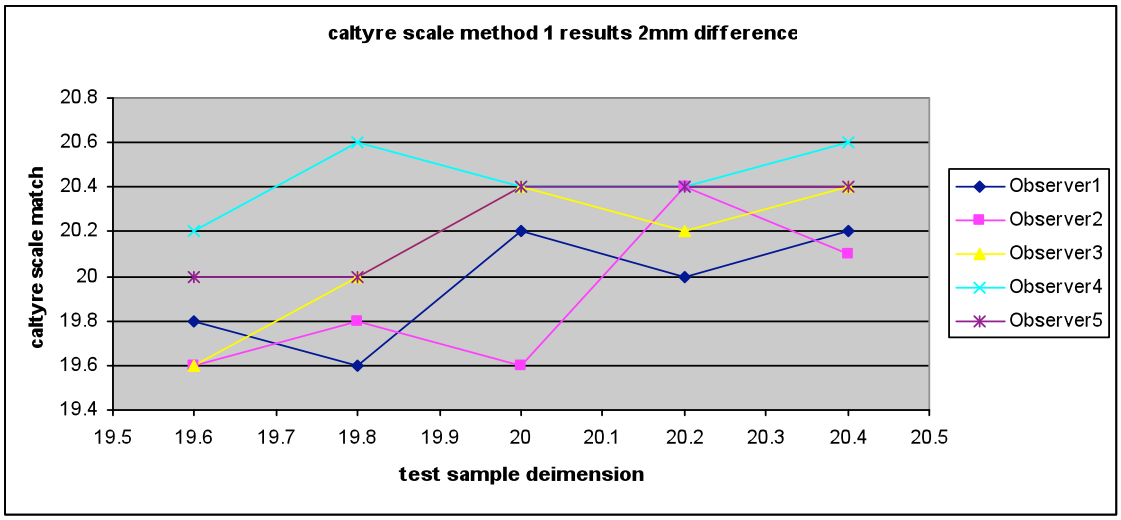


Figure 4.20 - Visual Samples matched to Caltyre Scale at a 2 mm difference

Figure 4.20 shows that no observer was able to match the visual samples to the Caltyre Scale perfectly for all 2 mm samples. Observer 3 matched 3 samples perfectly. Observer 2 matched 2 samples perfectly. 2 observers matched only 1 sample perfectly. 1 observer failed to match any samples. Therefore these observers were able to match 2 mm difference samples with difficulty.

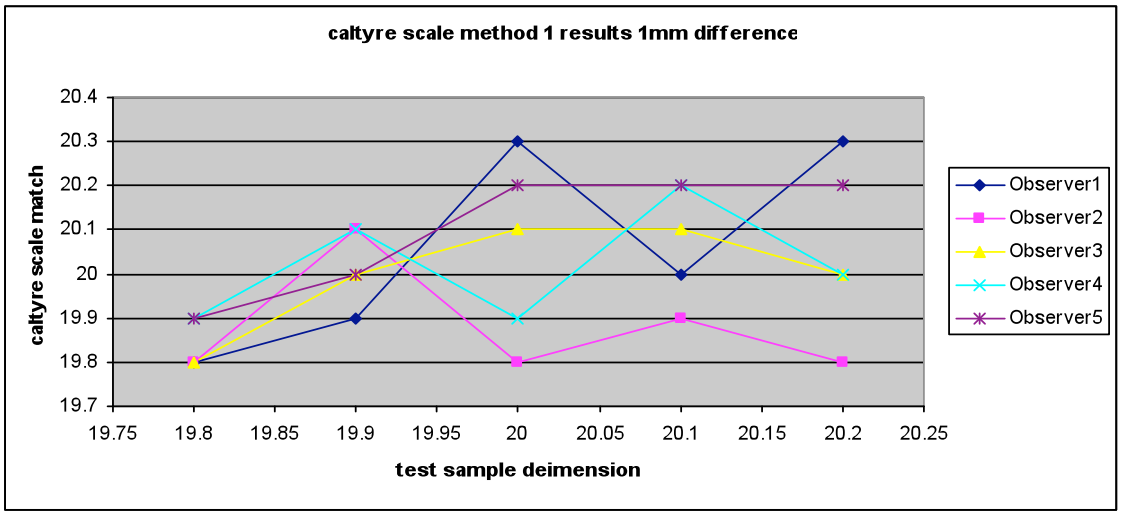


Figure 4.21 - Visual Samples matched to Caltyre Scale at a 1 mm difference

Figure 21 shows that no observer was able to match the visual samples to the Caltyre Scale perfectly for all 1 mm samples. 2 observers matched 2 samples perfectly and 2 observers matched 1 sample perfectly. The remaining observer failed to match any samples. Therefore these observers were unable to match 1 mm difference samples with any efficiency. See Appendix G for full results.

4.3 Evaluation of 'the Caltyre scale' method version 2 and version 3

Version 2 and 3 of the Caltyre scale used the same visual samples and Caltyre Scale Standards that are described in Section 4.2.10, but was presented in a different way from Version 1. There were 16 experiments in total, 4 experiments using each of 4 versions of the Caltyre Scale: a 4 mm difference Caltyre Scale (CS), 3 mm CS, 2 mm CS and 1 mm CS. In each experiment 10 observers were shown a Visual Sample and 5 Caltyre Scale Standards shown in turn. These were presented following a similar method as the paired comparison test, described in Section 4.2.6. For each Caltyre Scale the following 4 experiments were:

- Experiments 1 and 2 (version 2) involved asking the observer to 'please point to the sample that has the bigger inner square or state that they are the same'.
- Experiments 3 and 4 (version 3) asked the observer to 'please point to the sample that has the bigger inner square'.

- Experiments 1 and 3 compared a 20 cm inner square to 5 standards of the Caltyre Scale at 4 mm, 3 mm, 2 mm and 1 mm.
- For the 4 mm tests, experiments 2 and 4 compared a 19.2 cm inner square to 5 standards of the 4 mm difference Caltyre scale.
- For the 3 mm tests, experiments 2 and 4 compared a 20.3 cm inner square to 5 standards of the 3 mm difference Caltyre scale.

Appendix H shows that a positive number was assigned where the VS was bigger than the CSS, a negative number was assigned where the observer said that the CSS was bigger than the VS (or VS smaller than CSS). The numbers were assigned as follows for the 4 different size experiments;

- 4 mm difference assigned a +4 when the VS was bigger than the CSS, a -4 when the CSS was bigger than the VS and a 0 when they were the same
- mm difference assigned a +3 when the VS was bigger than the CSS, a -3 when the CSS was bigger than the VS and a 0 when they were the same
- mm difference assigned a +2 when the VS was bigger than the CSS, a -2 when the CSS was bigger than the VS and a 0 when they were the same
- 1 mm difference assigned a +1 when the VS was bigger than the CSS, a -1 when the CSS was bigger than the VS and a 0 when they were the same

4.3.1 Ideal result

Ideal results for experiments where observers were asked which inner square is bigger or if they are the same.

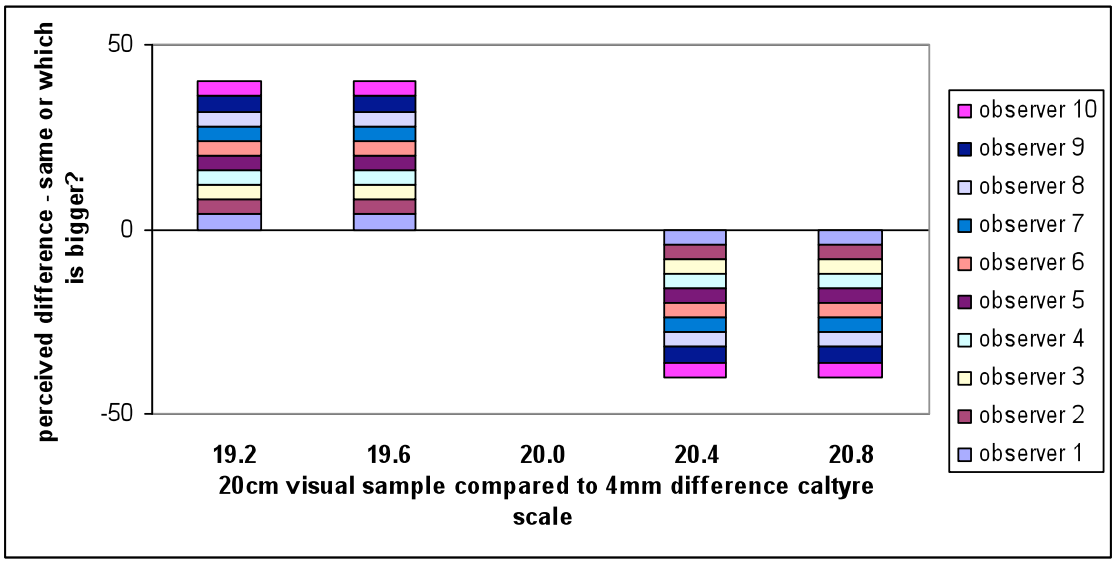


Figure 4.21 - bigger smaller same ideal result (nominal Caltyre 4 mm)

Figure 4.21 shows the following idealised result from 10 fictional observers:

- when shown the 19.2 cm CSS and the 20 cm VS all fictional observers selected the 20 cm VS as bigger than the 19.2 cm CSS;
- all fictional observers selected the 20 cm VS as bigger than the 19.6 cm CSS;
- all fictional observers stated that the 20 cm VS was the same as the 20 cm CSS;
- all fictional observers selected the 20.4 cm CSS as bigger than the 20 cm VS;
- all fictional observers selected the 20.8 cm CSS as bigger than the 20 cm VS.

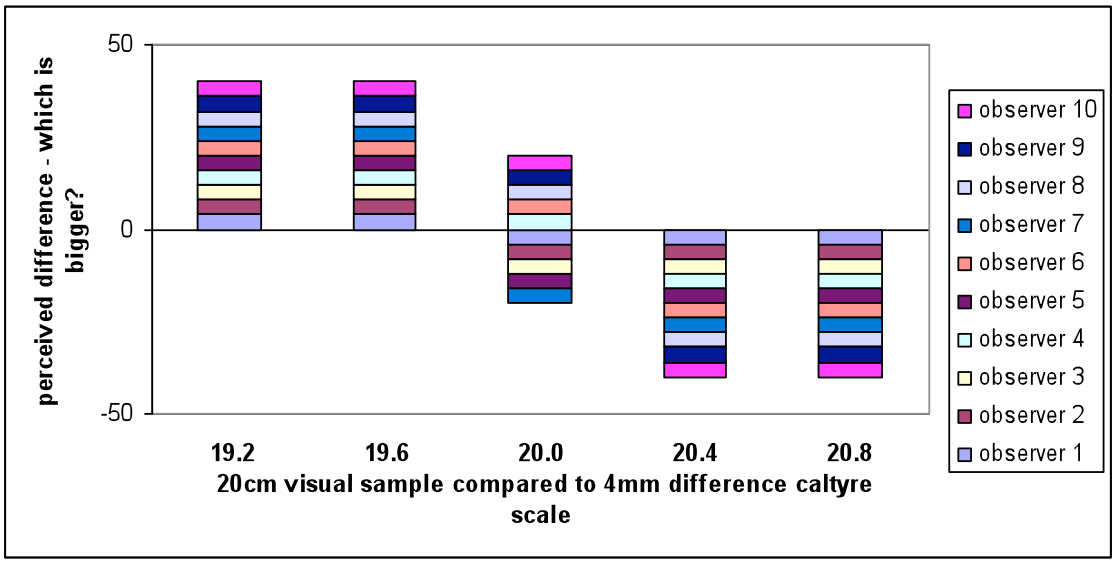


Figure 4.22 – ideal result for tests where observers asked to identify which inner square was bigger

Figure 4.22 shows ideal result obtained from 10 fictional observers asked to identify which inner square was bigger. Figure 4.22 shows the following:

- when shown the 19.2 cm CSS and the 20 cm VS all fictional observers selected the 20 cm VS as bigger than the 19.2 cm CSS;
- all fictional observers selected the 20 cm VS as bigger than the 19.6 cm CSS;
- there was not an option in this test for observers to say that the 2 identically sized inner squares (of 20 cm CSS and 20 cm VS) were the same, therefore the best result possible in this experiment would be for half the observers to say that the CSS was bigger and the other half to say that the VS was bigger – thus cancelling each other out;
- all fictional observers selected the 20.4 cm CSS as bigger than the 20 cm VS;
- all fictional observers selected the 20.8 cm CSS as bigger than the 20 cm VS

4.3.2 Evaluation of 4 mm difference Caltyre scale

Version 2 and version 3 of the Caltyre scale used the same visual samples and Caltyre scale standards that are described in Section 4.2.1. There were 4

experiments where observers were shown a visual sample and a Caltyre scale standard, presented in the same way as during the paired comparison test. Refer to Section 4.2.9.

- Experiments 1 and 2 (version 2) involved asking the observer 'please point to the sample that is bigger or state that they are the same'
- Experiments 3 and 4 (version 3) asked the observer 'please point to the sample that is bigger'
- Experiments 1 and 3 compared a 20 cm inner square Visual Sample to 5 standards of the 4 mm difference Caltyre Scale
- Experiments 2 and 4 compared a 19.2 cm inner square Visual Sample to 5 standards of the 4 mm difference Caltyre Scale

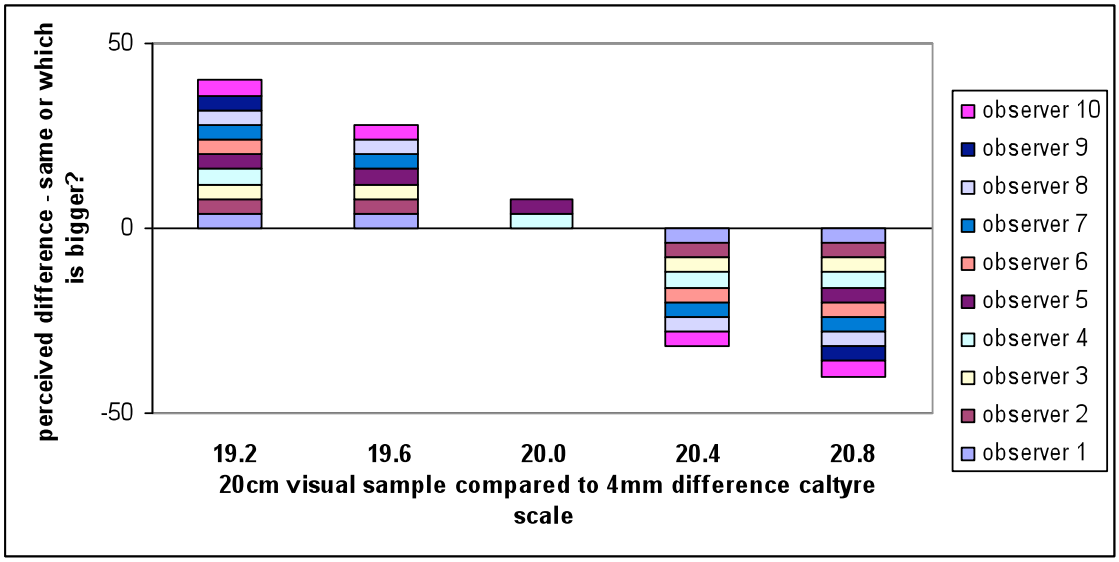


Figure 4.23 – Results of experiment 1, comparing 20 cm Visual Samples to 4 mm difference Caltyre Scale, same or which is bigger?

Appendix H.1 shows that observers managed to perceive a 4 mm difference with 70% to 100% accuracy for experiment 1.

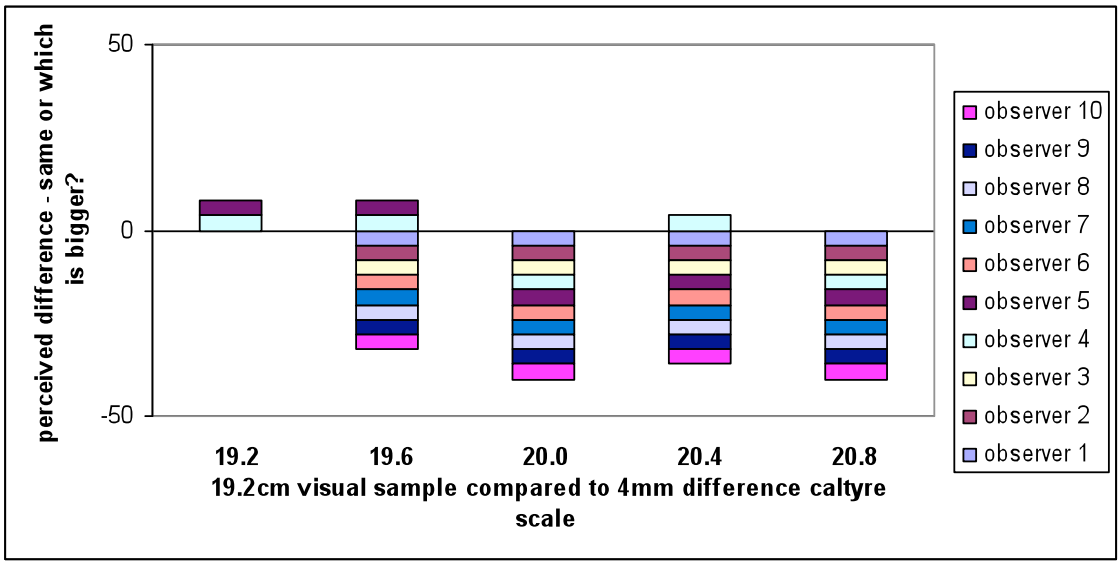


Figure 4.24 - Results of experiment 2, comparing 19.2 cm visual sample to 4 mm difference Caltyre scale, same or which is bigger?

Appendix H.2. shows that observers managed to perceive a 4 mm difference with 80% to 100% accuracy for experiment 2.

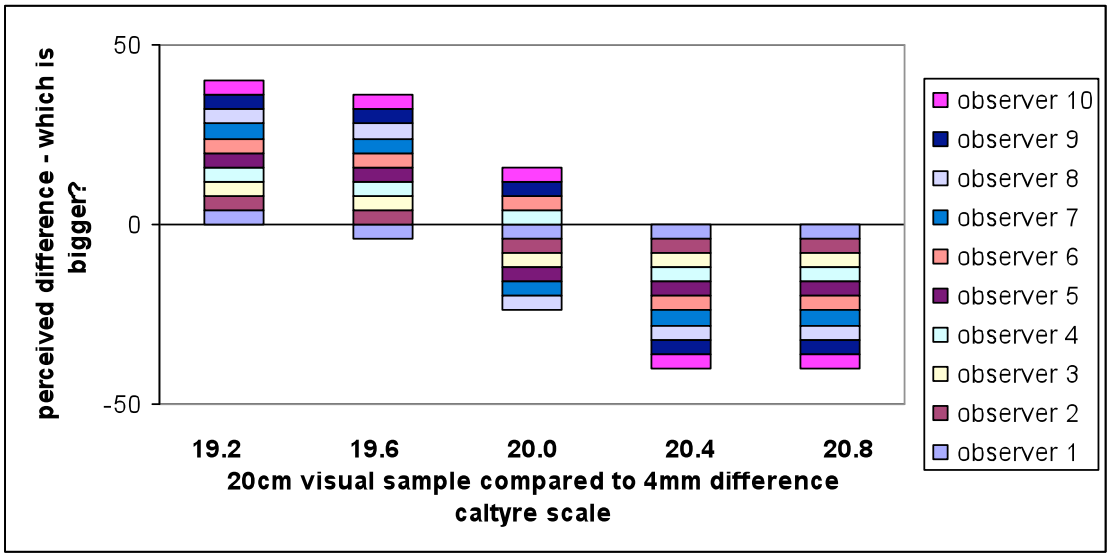


Figure 4.25 – Results of experiment 3, comparing 20 cm visual samples to 4 mm difference Caltyre scale, which is bigger?

Appendix H.3. shows that observers managed to perceive a 4 mm difference with 90% to 100% accuracy for experiment 3.

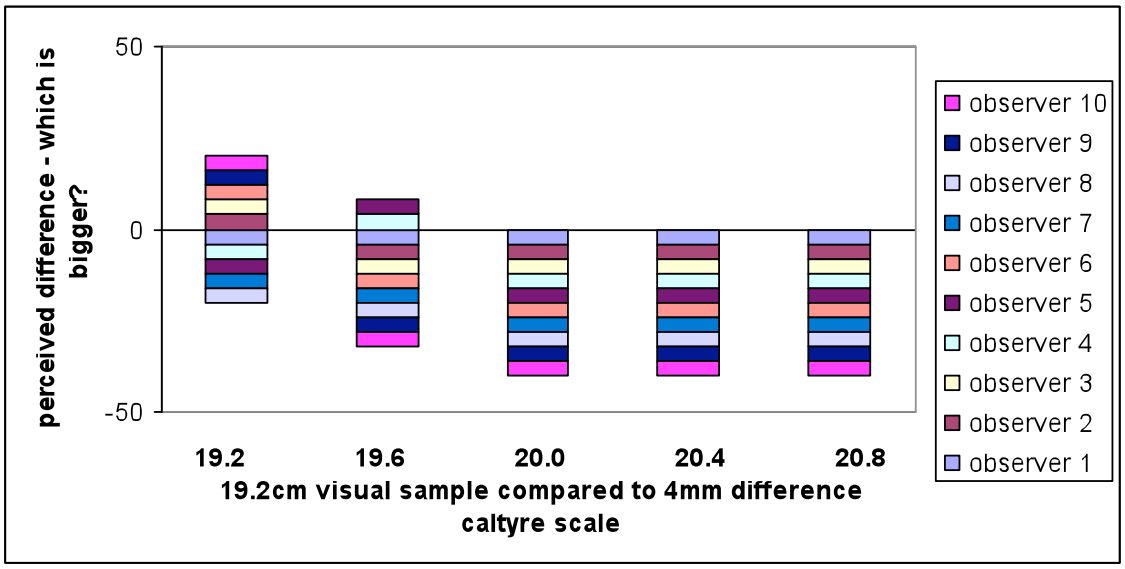


Figure 4.26 – Results of experiment 4, comparing 19.2 cm visual samples to 4-mm difference Caltyre scale, which is bigger?

Appendix H.4. shows that observers managed to perceive a 4 mm difference with 80% to 100% accuracy for experiment 4.

4.3.3 *Evaluation of 3 mm difference Caltyre scale*

Versions 2 and 3 of the Caltyre scale method used the same visual samples and Caltyre scale standards that are described in Section 4.2.1. There were 4 experiments where observers were shown a visual sample and a Caltyre scale standard, presented in the same way as during the paired comparison test. Refer to Section 4.2.9.

- Experiments 1 and 2 (version 2) involved asking the observer 'please point to the sample that is bigger or state that they are the same'
- Experiments 3 and 4 (version 3) asked the observer 'please point to the sample that is bigger' inner square
- Experiments 1 and 3 compared a 20 cm inner square visual sample to 5 standards of the 3 mm difference Caltyre scale
- Experiments 2 and 4 compared a 20.3 cm inner square visual sample to 5 standards of the 3 mm difference Caltyre scale

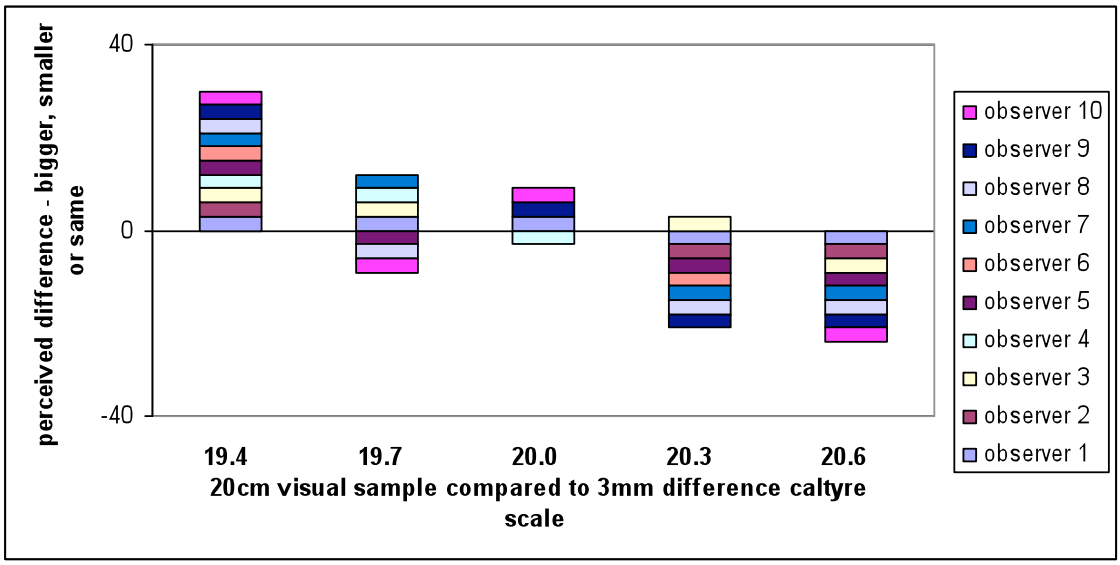


Figure 4.27 - Results of experiment 1, comparing 20 cm visual samples to 3 mm difference Caltyre scale, same or which is bigger?

Appendix H.5. shows that observers managed to perceive a 3 mm difference with 40% to 100% accuracy for experiment 1.

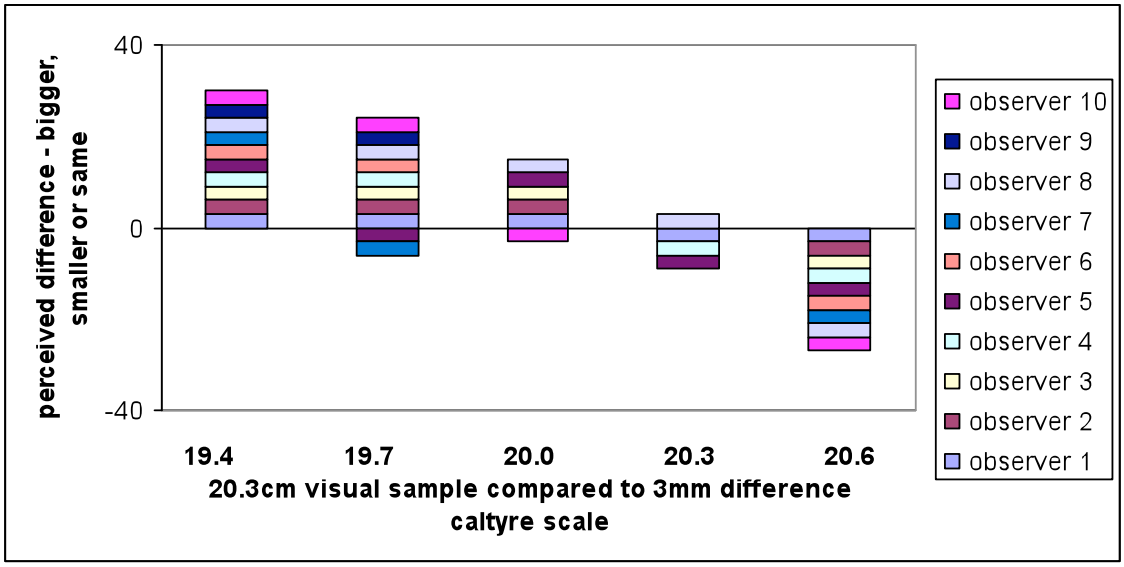


Figure 4.28 - Results of experiment 2, comparing 20.3 cm visual sample to 3 mm difference Caltyre scale, same or which is bigger?

Appendix H.6. shows that observers managed to perceive a 3 mm difference with 50% to 100% accuracy for experiment 2.

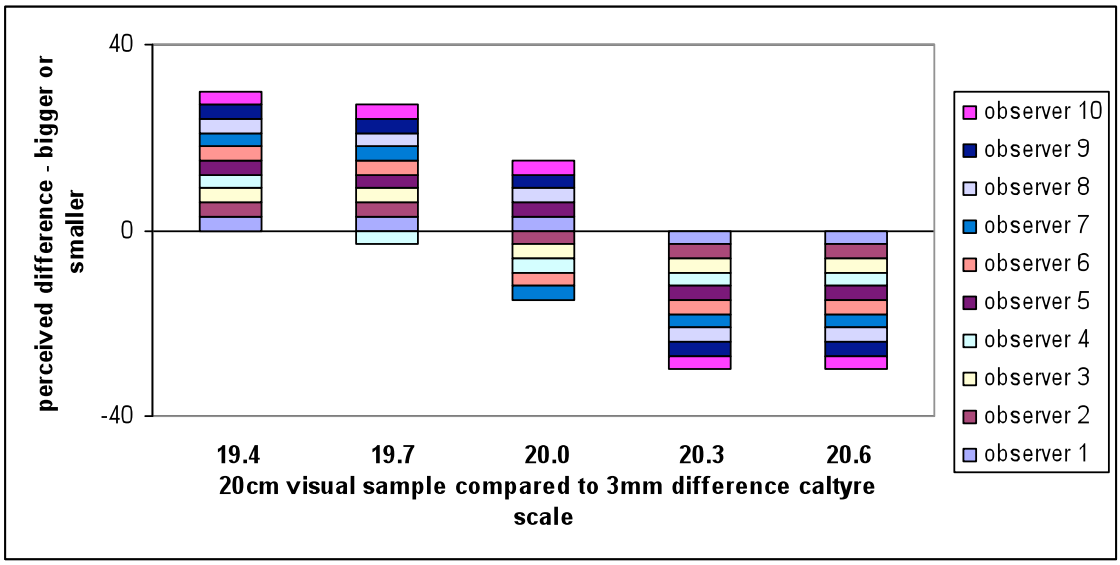


Figure 4.29 – Results of experiment 3, comparing 20 cm visual samples to 3 mm difference Caltyre scale, which is bigger?

Appendix H.7. shows that observers managed to perceive a 3 mm difference with 90% to 100% accuracy for experiment 3.

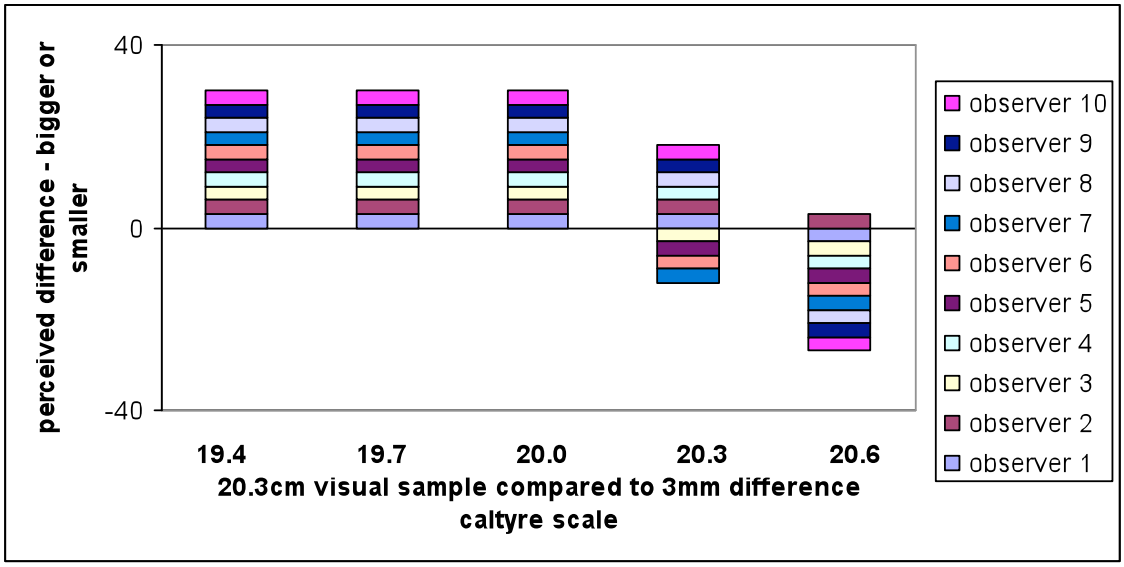


Figure 4.30 – Results of experiment 4, comparing 20.3 cm visual samples to 3 mm difference Caltyre scale, which is bigger?

Appendix H.8. shows that observers managed to perceive a 3 mm difference with 90% to 100% accuracy for experiment 4.

4.3.4 *Evaluation of 2 mm difference Caltyre scale*

Versions 2 and 3 of the Caltyre scale method used the same visual samples and Caltyre scale standards that are described in Section 4.2.1. There were 4 experiments where observers were shown a visual sample and a Caltyre scale standard, presented in the same way as during the paired comparison test. Refer to Section 4.2.9.

- Experiments 1 and 2 (version 2) involved asking the observer 'please point to the sample that is bigger or state that they are the same'
- Experiments 3 and 4 (version 3) asked the observer 'please point to the sample that is bigger' inner square
- Experiments 1 and 3 compared a 20 cm inner square visual sample to 5 standards of the 1 mm difference Caltyre scale
- Experiments 2 and 4 compared a 20.4 cm inner square visual sample to 5 standards of the 2 mm difference Caltyre scale

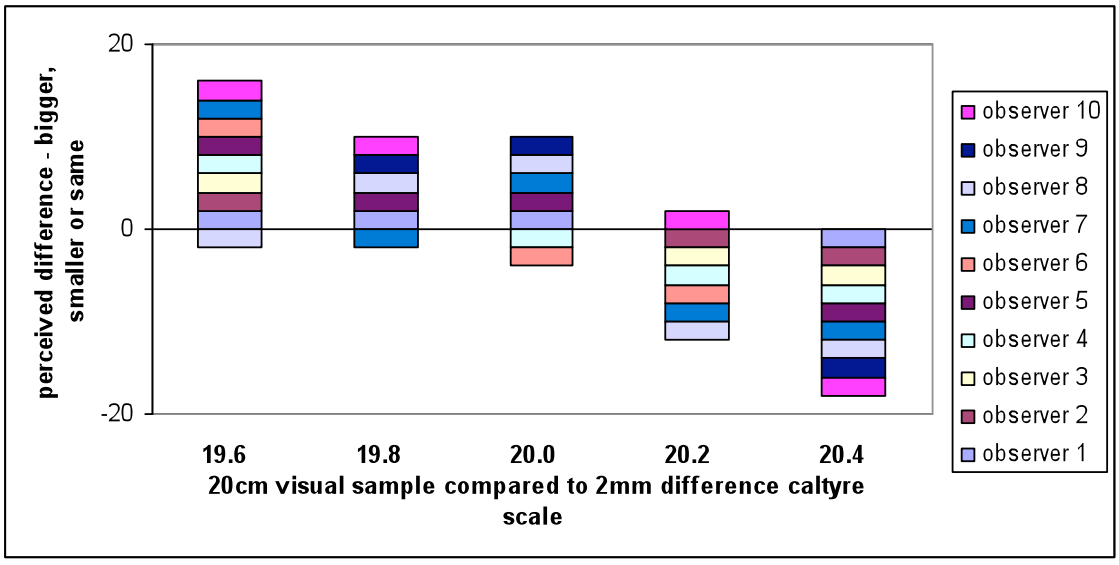


Figure 4.31 - Results of experiment 1, comparing 20 cm visual samples to 2 mm difference Caltyre scale, same or which is bigger?

Appendix H.9. shows that observers managed to perceive a 2 mm difference with 30% to 90% accuracy for experiment 1.

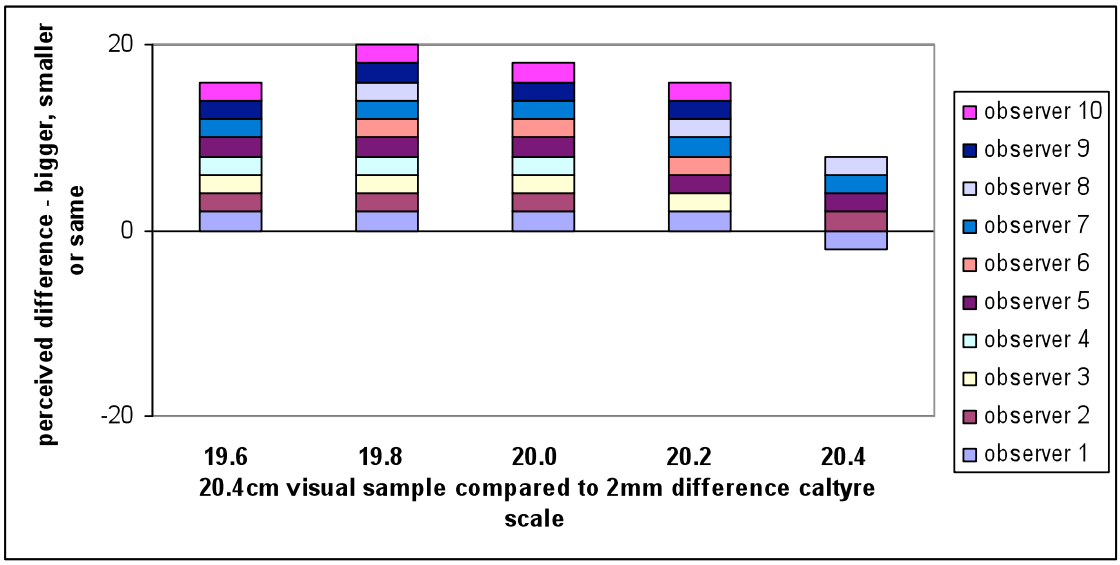


Figure 4.32- Results of experiment 2, comparing 20.4 cm visual sample to 2 mm difference Caltyre scale, same or which is bigger?

Appendix H.10. shows that observers managed to perceive a 2 mm difference with 50% to 100% accuracy for experiment 2.

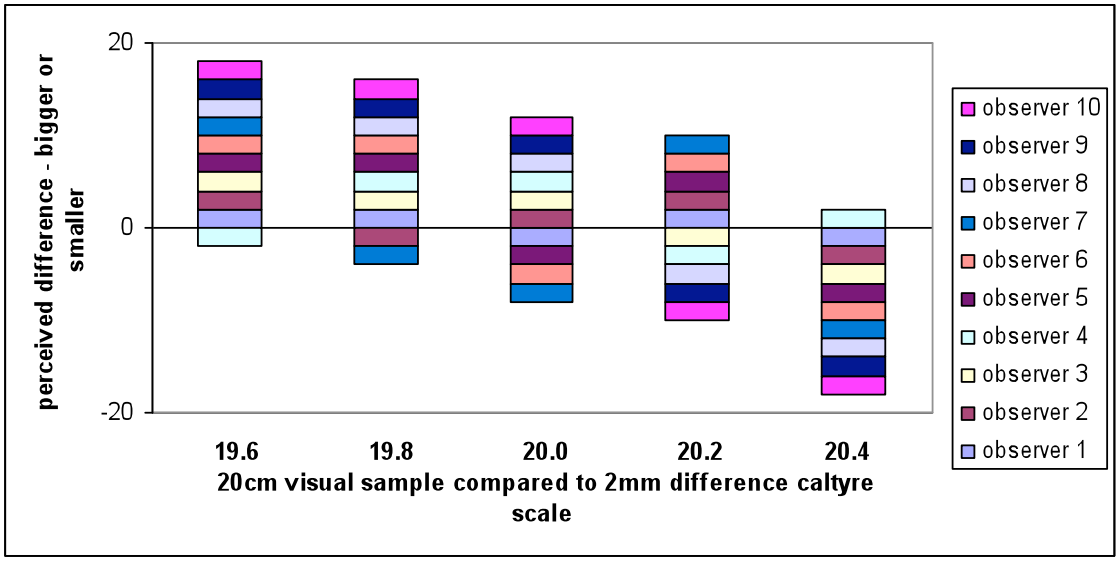


Figure 4.33 – Results of experiment 3, comparing 20 cm visual samples to 2 mm difference Caltyre scale, which is bigger?

Appendix H.11. shows that observers managed to perceive a 2 mm difference with 50% to 90% accuracy for experiment 3.

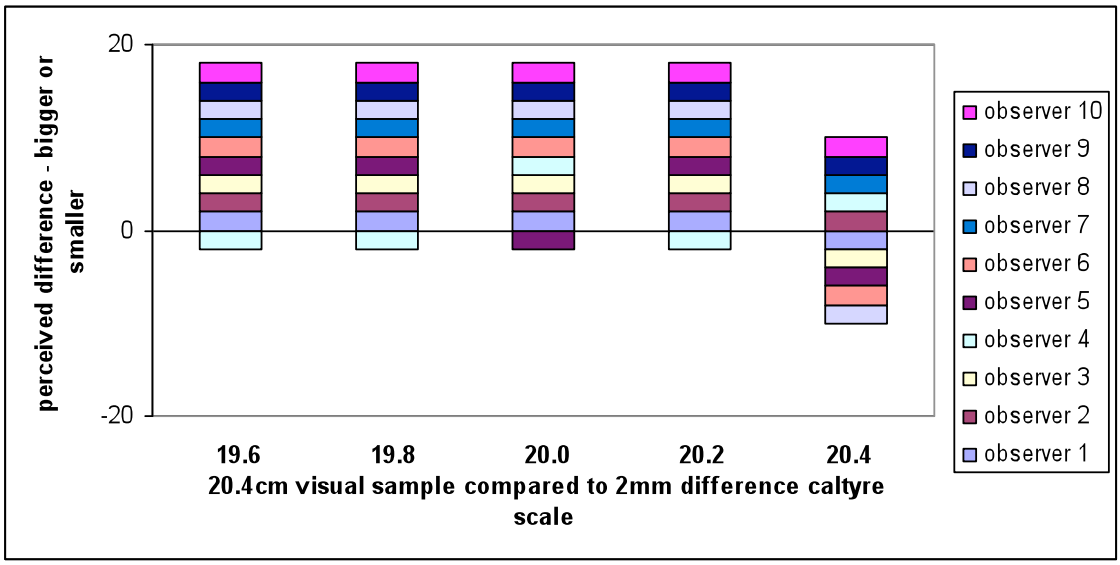


Figure 4.34 – Results of experiment 4, comparing 20.4 cm visual samples to 2-mm difference Caltyre scale, which is bigger?

Appendix H.12. shows that observers managed to perceive a 2 mm difference with 90% accuracy for experiment 4.

4.3.5 *Evaluation of 1 mm difference Caltyre scale*

Versions 2 and 3 of the Caltyre scale method used the same visual samples and Caltyre scale standards that are described in Section 4.2.1. There were 4 experiments where observers were shown a visual sample and a Caltyre scale standard, presented in the same way as during the paired comparison test. Refer to Section 4.2.9.

- Experiments 1 and 2 (version 2) involved asking the observer 'please point to the sample that is bigger or state that they are the same'
- Experiments 3 and 4 (version 3) asked the observer 'please point to the sample that is bigger' inner square
- Experiments 1 and 3 compared a 20 cm inner square visual sample to 5 standards of the 1 mm difference Caltyre scale
- Experiments 2 and 4 compared a 19.9 cm inner square visual sample to 5 standards of the 1 mm difference Caltyre scale

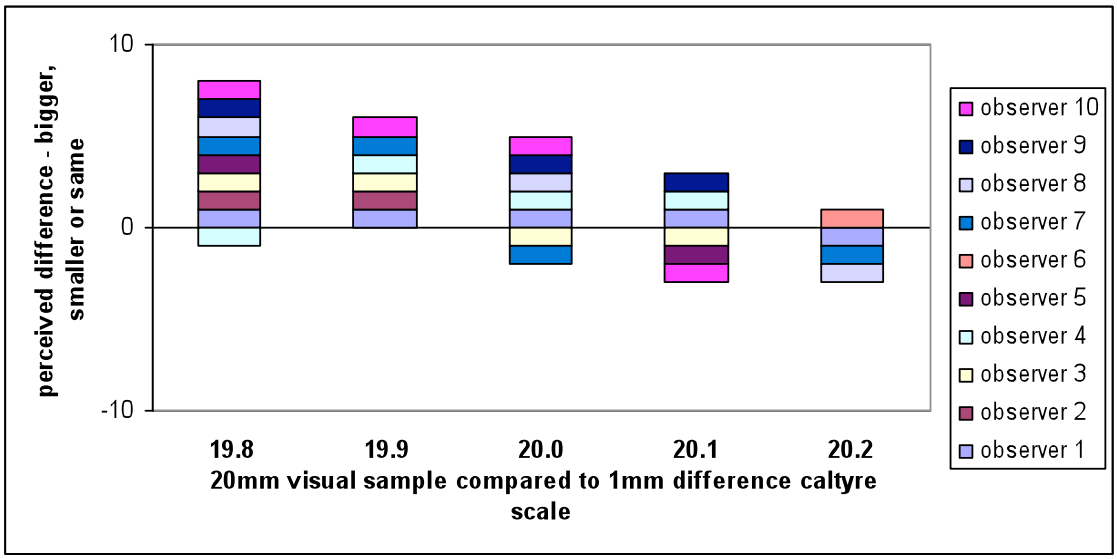


Figure 4.35 - Results of experiment 1, comparing 20 cm visual samples to 1 mm difference Caltyre scale, same or which is bigger?

Appendix H.13. shows that observers managed to perceive a 1 mm difference with 30% to 80% accuracy.

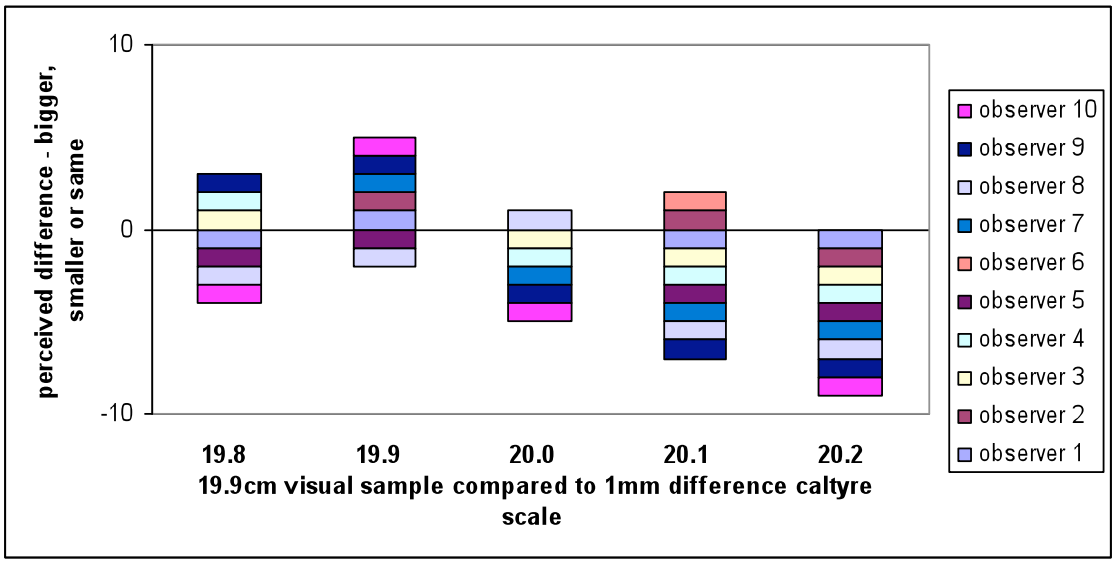


Figure 4.36- Results of experiment 2, comparing 19.9 cm visual sample to 1 mm difference Caltyre scale, same or which is bigger.

Appendix H.14. shows that observers managed to perceive a 2 mm difference with 30% to 90% accuracy for experiment 2.

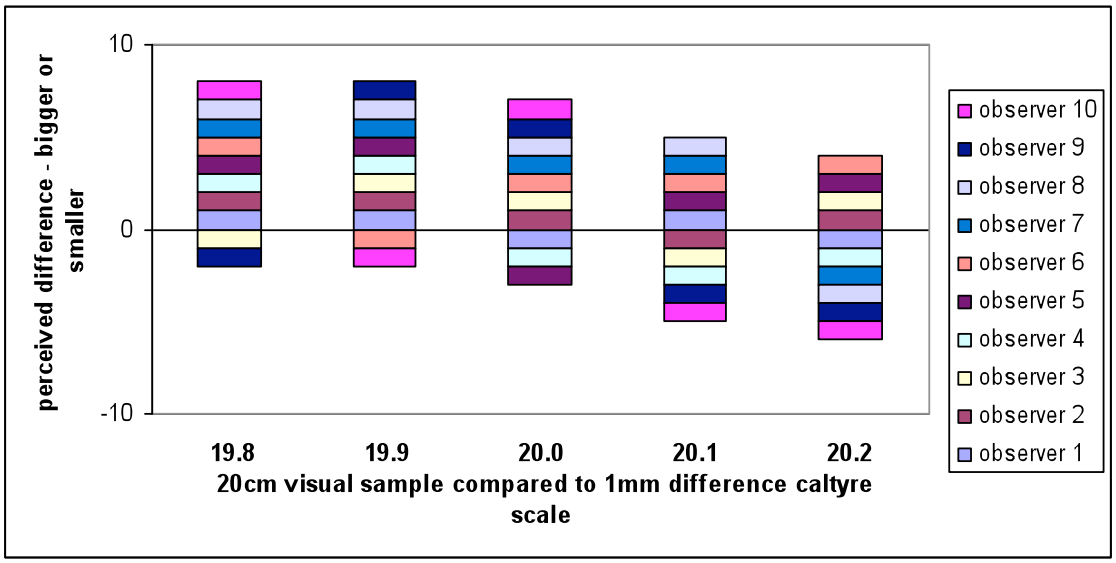


Figure 4.37 – Results of experiment 3, comparing 20 cm visual samples to 1 mm difference Caltyre scale, which is bigger?

Appendix H.15. shows that observers managed to perceive a 1 mm difference with 50% to 80% accuracy for experiment 3.

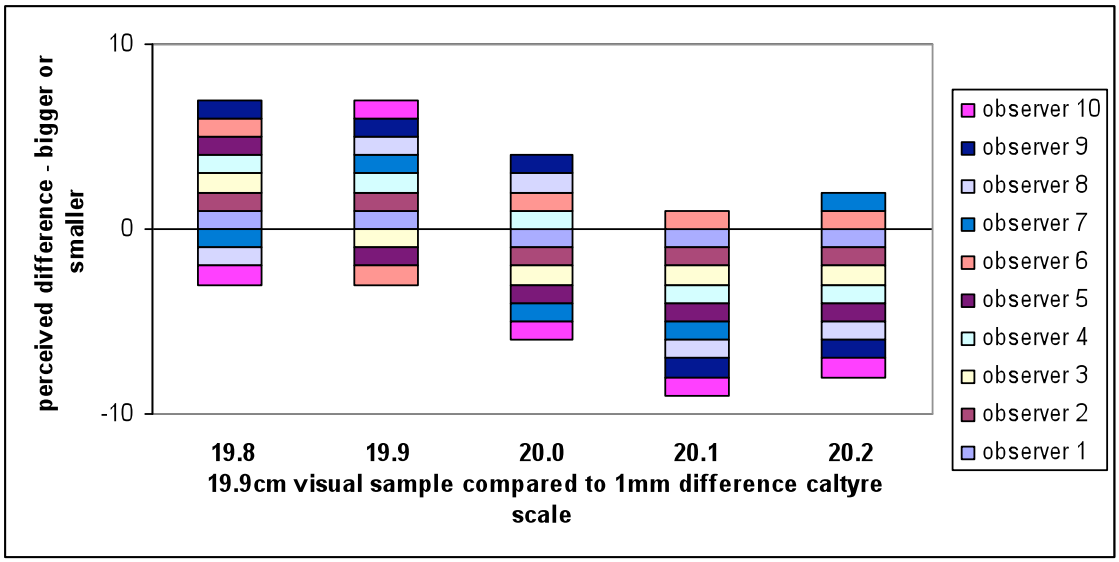


Figure 4.38 – Results of experiment 4, comparing 19.9 cm visual samples to 1-mm difference Caltyre scale, which is bigger?

Appendix H.16. shows that observers managed to perceive a 1 mm difference with 60% to 80% accuracy for experiment 4.

All of the above experiments were repeated in the same manner with a change to the question. The observers were asked 'please tell me which square is

bigger?" This was deemed to be a forced response. The results of these experiments are detailed in Appendixes H1-16.

4.4 Conclusion of results of experiments to find method

The experiments described in this chapter were conducted to inform further research in two ways. First, they were designed to assess the ability of observers to perceive size differences in the visual samples. Second, the quality of results would influence the choice of method used in subsequent investigations.

The first set of experiments where observers were asked to rank samples in order of smallest to biggest, narrowest to widest and smallest to tallest showed that using a small number of observers gave a result that was satisfactory. Therefore, in order to reliably measure real differences in size by ranking, 12 observers could be used. However, Experiments 4 and 5, detailed in section 4.1, suggested that in order to measure perceived differences in size where the 'difference' is created using optical illusion rather than real dimensional difference it would seem that more observers would be needed and/or a more dramatic illusional difference and/or a more robust method of evaluation should be used. This was explored briefly in experiment 4 and experiment 5, detailed in section 4.1, where observers were asked to rank rectangles of different length from narrowest to widest and asked to rank rectangles of different width from shortest to longest

After rigorous testing of three methods - paired comparison, ranking and rating with the Caltyre Scale the following conclusions were drawn:

Initial experiments using 2D black squares showed that observers could perceive size differences in the samples of between 1 mm and 4 mm.

Paired Comparison appeared the easiest of all the tests for the observers to understand and was also the test that was performed the fastest out of all 3. Observers did not ask any questions and managed the test easily and relatively quickly. This was the simplest test for the observers and the tester. The time

to complete this method of testing was an average 20 minutes for 4 experiments. The time that observers took to understand and complete the tests are critical as they began to tire after more than 20 minutes and concentration levels were less, which in turn impaired their perceptions resulting in less accurate results.

The Ranking test was a fairly easy test for the observers to grasp and was the second fastest test to perform and complete. Observers tended to use informal paired comparison techniques during this test, i.e. they compared 2 samples at a time when deciding on the order. The test was also performed in the light box but problems arose when trying to fit the 5 sample cards into the box to create a smallest to biggest ranking, because it was only wide enough to accommodate 4 samples side by side.

The use of The Caltyre Scale was the most frustrating and difficult method used for testing, for both the observers and the tester. Observer's comments were that it was difficult, frustrating, upsetting and time consuming. Each sample took on average 5 minutes to place and in some cases this rose to 10 – 15 minutes, therefore between 25 and 75 minutes for the whole test. The results were not as good as hoped. The test took far too long to perform so observers were losing concentration and appeared to be guessing rather than striving for accuracy.

Although giving better results, the revised use of The Caltyre Scale, named version 2 and 3 were still proving to be problematic in their execution. Observers' comments were that it was still confusing and time consuming in a similar way to the first Caltyre Scale experiments. Each sample took on average 5 minutes to place and in some cases this rose to 10 minutes, therefore between 25 and 50 minutes for the whole test. The results were still not as good as hoped. The test took far too long to perform so observers were losing concentration and interest and once again appeared to be guessing rather than striving for accuracy.

After rigorous testing of three methods - paired comparison, ranking and rating with the Caltyre Scale, it was concluded that the best overall method for this research was paired comparison. This conclusion was based on the following:

- Observers seemed to find this method of visual assessment the simplest to understand and the fastest to perform.
- Whether they were required to rank the samples from smallest to largest, or, later, when they were being asked to rate samples against the Caltyre Scale, observers tended to use an informal method of paired comparison regardless of instruction, to come to their conclusions.

A tentative desktop computer based paired comparison test was set up using Microsoft Power Point. Black squares with a visual area of 20 cm x 20 cm, 20.3 cm x 20.3 cm and 20.6 cm x 20.6 cm were paired with 20 cm x 20 cm monochromatic optical patterned squares displaying stripes, checks and spirograph patterns to imitate a more organic aesthetic which are detailed and discussed in detail in The Digital Sketch Books. This iterative test can be seen in Appendix J. A small number of observers were approached to trial the tests and the format proved to be successful as it was very quick to perform. This interim stage in survey design informed the format that was undertaken for the next stage of testing that is detailed in Chapter 5.

Since it was deemed that a higher number of observers was needed for further testing and these extra participants could be most easily contacted electronically, it was decided to use paired comparison in a web based format, refer to Chapter 2, Section 2.5.

A key aim of this research project is to try to find a method by which the perception of the female form can be measured. The most appropriate method was sought for investigating the influence of surface printed monochromatic optical pattern on the human perception of size, and by creating a conceptual design collection to demonstrate the perception of size caused by the optical effects of printed design on textiles.

Great care was taken to fully investigate all scientific methods employed by previous research on which this investigation is based. However, as described in the above test results and their evaluation, the relatively simple method of paired comparison proved to be of most value to the key aim of designing a collection which could be presented and evaluated to the greatest effect.

4.5 References

British Standards Institution (2001) BS EN ISO 15487:2001. Textiles – Method for assessing appearance of apparel and other textile end products after domestic washing and drying. Brussels: BSI

Itten, J. (1992) The Elements of Colour; a treatise on the colour, London: Chapman and Hall

Chapter 5 – Capturing Optical Illusions on a Dress

After careful consideration of the results of the experimentation described in Chapter 4, the decision was made to use the paired comparison method to progress this research. A survey was constructed in which images of black and white optically patterned dresses were presented. Participants were asked to make choices based on their visual perception of which dress appeared bigger.

5.1 Experimental dress

It was decided that for the purposes of this study an experimental dress which could be used as a basis for all prints would be designed and made. Two dress shapes were considered - a classic shift dress in a white cotton drill fabric and a body conscious dress in a white cotton Lycra (see Section 5.1.2).

5.1.1 Design choice and development

The first monochromatic optical patterns selected for experimentation and further development were based on the Herring illusion and the Wundt illusion (discussed in Chapter 3 section 3.2.1 and Chapter 3 section 3.3, see Figure 5.1) which give the illusion of parallel lines curving depending on which way diagonal lines are crossing them. The aim was to determine whether these two illusions would still create the same effect once printed on a dress and worn on the body as they do when presented in a 2-D format. It was expected that the Herring illusion would give the impression of a fuller figure at the point where the diagonal lines met and the vertical lines bulged, as the vertical lines give a bulging effect and appear to be convex. It was expected that the Wundt illusion would give a slimming or narrowing effect on the area of the female form wherever the centre of the design was placed, as the vertical lines appear to bend inwards giving a concave effect.

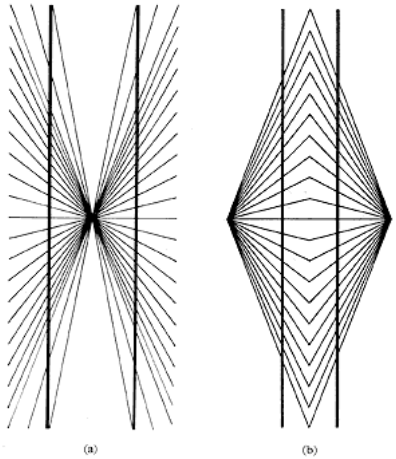


Figure 5.1 – (a) Herring and (b) Wundt illusions

Initially only a white dress was developed and the chosen two designs were applied to the dress via various methods which are explained further in this chapter.

5.1.2 *Designing the dress*

The fact that fashion trends are cyclical and that dress shapes change with the seasons made deciding on a current dress shape, which would look timeless, an important factor. Two dress shapes have recurred in recent fashion history. The first is a body conscious (body con) dress, which fits the form of the female body closely. This dress was designed and a pattern was made using the Lectra Design CAD software. The dress was made up using a cotton stretch Lycra material.

The second dress shape is a classic shift dress. This dress is a timeless design that can be developed to fit into any recent era. The pattern for this dress was also developed using the Lectra design CAD software. The dress was then made up in a coated 255gsm cotton drill.

These two white dress designs, a body conscious design and a classic shift, were produced in full UK size 12 garments

5.1.3 *Pattern selection*

The initial experiment used designs based on the Herring illusion and the Wundt illusion (discussed in Chapter 3 section 3.2.1 and Chapter 3 section 3.3, see Figure 5.1). The designs were printed directly onto the dresses using traditional hand screen-printing techniques. The aim was to determine whether the illusions would still create the same effect once printed on a dress and worn on the female form. It was expected that the Herring illusion would give the impression of a larger figure as the vertical lines give a bulging effect and appear to be convex. It was expected that the Wundt illusion would give a slimming effect, as the vertical lines appear to bend inwards giving a concave effect.

Each illusion was printed onto the body con dress and the shift dress, giving a total of 4 printed dresses.

An additional shift dress was digitally printed with the Herring illusion. This was tried because it was considered easier to manipulate the design using digital printing methods than to have to manually print a series of dresses with slightly different versions of an illusion until a satisfactory result could be achieved. This decision is discussed later in this chapter.

5.1.4 *Fabric selection*

The initial fabric was selected to achieve the best possible look depending on the monochromatic optical pattern so as to give the best possible effect.

The body conscious dresses had to be made from cotton Lycra as it had to easily fit to the shape of the female form. The dress pattern was cut out and designs were printed onto the dress shapes. This fabric was printed using traditional screen-printing methods and was achieved using black pigment dye paste and black reactive dye. The dresses were then made into garments, (Figures 5.2, 5.3 and 5.4).

Figure 5.2 - Body con cotton lycra dress, black reactive dye, Hering design 1

Figure 5.3 – Body con cotton lycra dress, black pigment dye, Hering design 2

Figure 5.4 – Body con cotton lycra dress, black pigment dye, Hering design 3

The shift dress was made using a different fabric because it was decided that a stiffer fabric was needed to give some weight and structure to the garment. A 255gsm cotton drill fabric was chosen. As one of the dresses in cotton drill was

to be printed using the digital printer and would also be used in a plain unprinted version of the dress, an uncoated version was sought. However, the same weight of fabric was not available coated and uncoated so the decision was made to wash the coated fabric for the plain dress and continue using this fabric for digitally printed dresses. The digital printing method was discontinued, however, because irregular shrinkage occurred in the finishing process. The need to use the coated material was, therefore, no longer relevant and, in the end, a cotton sateen fabric was used (see Figure 5.5).

5.2 Inspiration for a change in process

The process of printing a potentially large number of dresses before a suitable result could be achieved was wasteful, expensive and time consuming. A faster more intuitive way of working was sought. A process of displaying several dresses to explore the possibilities of different monochromatic optical illusions as patterns was developed so that the need for printing was eliminated at this initial stage of experimentation. Instead of using the print process the researcher decided to use a digital projector and project the Herring and Wundt illusions onto a plain white dress to see if this would give the same end result as printing on the dress. Then photographs were taken to compare the two methods of monochromatic optical pattern application. Several artists, designers, photographers and fashion designers have used projections of designs as a method for creating interesting effects notably photographer John French and more recently fashion designer Hamish Morrow. The conclusions for this stage of the method are discussed in section 5.3. In tandem with this development of process, designs were also applied to dresses in a purely digital format using Adobe Photoshop where 2D mannequins were used as a basis for applying different monochromatic optical patterns to dresses (see Appendix K). This purely digital method of producing images was abandoned in favour of the projected method which gave faster and more realistic results.

5.3 The projected dress

The new method of showing monochromatic optical pattern on the dress needed several attempts to create a dress that could be perceived as real by

the observer. CAD was at first used to try and manipulate the monochromatic optical patterns chosen onto existing photographs. The software used was Adobe Illustrator. The end result was sketchy and unsatisfactory and also did not show a true representation of how the monochromatic optical pattern might look on the female form. This led to the experimentation of projecting designs direct from Adobe Photoshop through a data projector onto a plain white dress that had been placed on a tailor's dummy (see Digital Sketch Book, The Dress). This process produced a successful result and could be quickly manipulated and changed to achieve different effects. The next step in the process was to record the results so that they could then be shown to observers and perceptions could be gathered. The dresses were photographed using a small digital camera on a tripod set up at a distance that was uniform for all photographs taken.

After several variations of the same optical illusion were placed in different places on the dresses, the dresses were photographed and the photographs were manipulated. Using Adobe Photoshop, the photographs were changed from colour to greyscale to eliminate the issues that occur when photographing a RGB projection. The issues were that when a photograph was being taken the camera detected either a red, green or blue hue and applied this to the photographs. The photographs were also lightened using an auto contrast command to show a bigger contrast between black and white in the overall appearance.

To ascertain whether or not the projected dress (Figure 5.6) looked the same as a traditionally printed dress a printed dress also had to be photographed (Figure 5.5). A printed dress with the same monochromatic optical pattern as one of the projections was set up in the same room as the projected dresses had been photographed. The dress was photographed in the same conditions and then the image of the printed dress and the images of the projected dress were compared. After carefully observing both dresses to ensure that the projected monochromatic optical pattern matched the printed monochromatic optical pattern closely enough, it was deemed that the printed dress and the dress with the projected monochromatic optical pattern cleaned up using

Adobe Photoshop were of a similar enough nature to continue with the projected monochromatic optical pattern method.

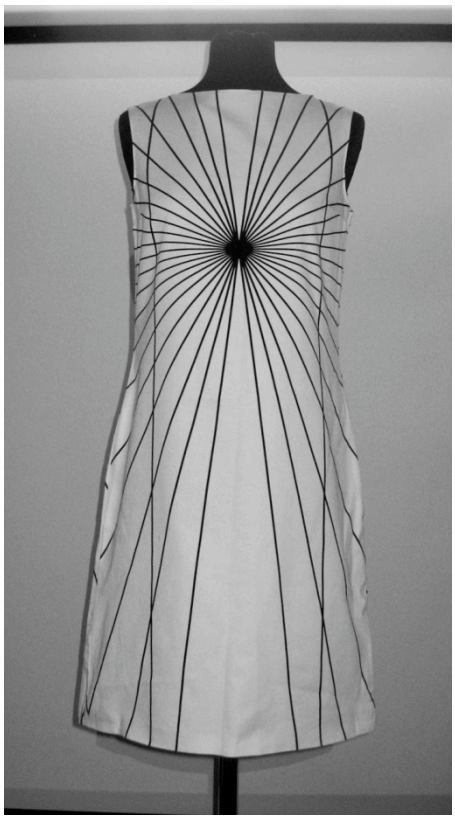


Figure 5.5 – Printed dress for comparison

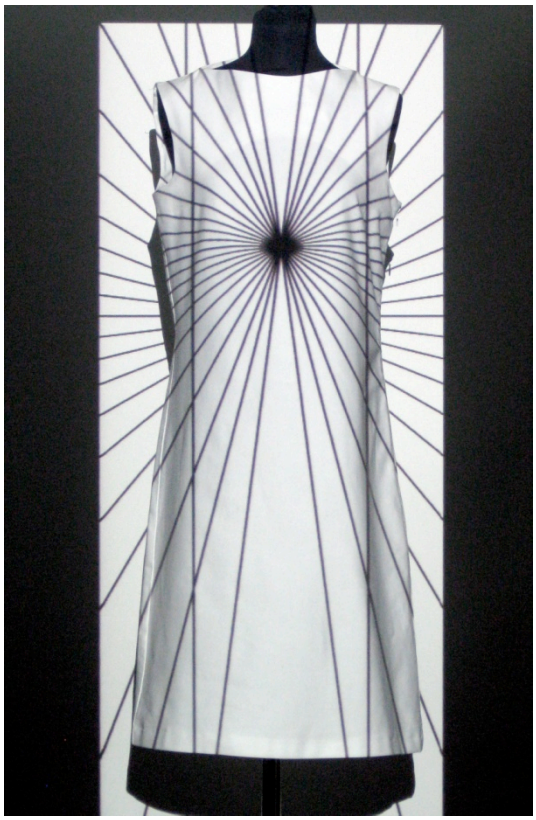


Figure 5.6 – Projected dress for comparison

5.4 Projected dress method and results

Photographs taken of the white dress with different monochromatic optical patterns projected onto it were then manipulated using Adobe Photoshop to remove the surrounding image (see Figure 5.7 and Figure 5.8) and were placed in pairs onto a plain white background (see Figure 5.9) and uploaded to Photobucket, an image hosting website (www.photobucket.com), which would in turn give a code which then enabled the photographs to then be uploaded to Bristol Online Survey (BOS) where a web survey was built. Several surveys were built and published online in an iterative process. The sequence of the first three surveys is presented below.

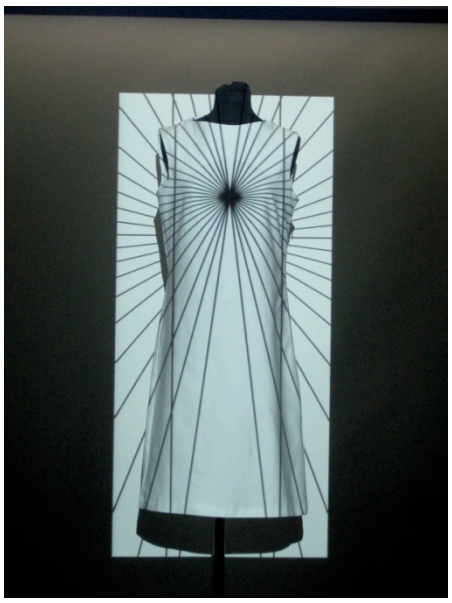


Figure 5.7 - Projection onto dress

Figure 5.8 - Cleaned Projection

BOS was used as a simple way of building a straightforward, paired comparison survey where the pairs of projected monochromatic optical pattern dresses could be evaluated and judged by the maximum number of observers possible in a short period of time.

Figure 5.9 - Pair of cleaned projected monochromatic optical pattern dresses for 1st BOS survey

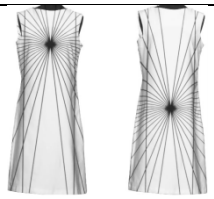
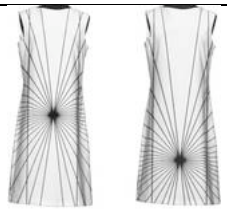
5.4.1 *Bristol Online Survey No 1- Which is Bigger?*

In the 1st survey built using BOS a selection of Projected Pattern Dresses (PPD) were arranged in pairs of combinations of the different 8 designs in black and white. All the white dresses were also presented as black dresses by inverting white to black in Adobe Photoshop.

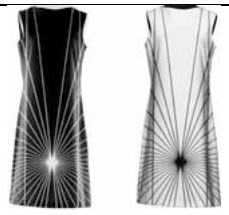
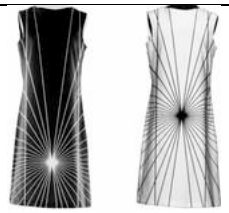
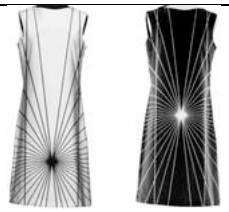
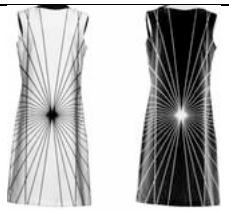
There were 25 pairs made of combinations out of a total of 4 black designs on a white dress and 4 white designs on black dress (inverted from the white designs using Adobe Photoshop). All the dresses were exactly the same size; the only differences were the different design projected onto each dress and whether the dresses were black or white.

The 1st survey, named 'Which is Bigger?' was launched on 07/10/2009 and results were collected up until 01/12/09. Observers were contacted through Heriot Watt University, School of Textiles and Design's webmail via a link in an email and the survey was also sent to various contacts throughout the UK covering a large demographic. Out of a total of 401 responses to the 'Which is Bigger?' survey 305 observers completed the survey and there were 96 uncompleted surveys.

The pairs of dresses and the results can be seen in the table below (Table 5.1).

1	WHICH IS BIGGER?		Left 23.3% 71	Right 76.7% 234
2	WHICH LOOKS BIGGER?		Left 21.3% 65	Right 78.7% 240
3	WHICH LOOKS BIGGER?		Left 38.7% 118	Right 61.3% 187
4	WHICH IS BIGGER?		Left 40.0% 122	Right 60.0% 183
5	WHICH LOOKS BIGGER?		Left 51.5% 157	Right 48.5% 148
6	WHICH IS BIGGER?		Left 51.8% 158	Right 48.2% 147
7	WHICH IS BIGGER?		Left 53.8% 164	Right 46.2% 141
8	WHICH IS BIGGER?		Left 55.7% 170	Right 44.3% 135

9	WHICH IS BIGGER?		Left 31.8% 97	Right 68.2% 208
10	WHICH IS BIGGER?		Left 46.6% 142	Right 53.4% 163
11	WHICH IS BIGGER?		Left 72.5% 221	Right 27.5% 84
12	WHICH IS BIGGER?		Left 62.0% 189	Right 38.0% 116
13	WHICH IS BIGGER?		Left 46.6% 142	Right 53.4% 163
14	WHICH IS BIGGER?		Left 31.5% 96	Right 68.5% 209
15	WHICH IS BIGGER?		Left 55.7% 170	Right 44.3% 135
16	WHICH IS BIGGER?		Left 59.3% 181	Right 40.7% 124

17	WHICH IS BIGGER?		Left 18.7% 57	Right 81.3% 248
18	WHICH IS BIGGER?		Left 25.2% 77	Right 74.8% 228
19	WHICH IS BIGGER?		Left 38.4% 117	Right 61.6% 188
20	WHICH IS BIGGER?		Left 47.5% 145	Right 52.5% 160
21	WHICH IS BIGGER?		Left 28.9% 88	Right 71.1% 217
22	WHICH IS BIGGER?		Left 54.1% 165	Right 45.9% 140
23	WHICH IS BIGGER?		Left 41.6% 127	Right 58.4% 178
24	WHICH IS BIGGER?		Left 19.7% 60	Right 80.3% 245

25	WHICH IS BIGGER?		Left 20.3% 62	Right 79.7% 243

Table 5.1 - Bristol Online Survey No 1- Which is Bigger?

The results showed some differences observed between optical patterns and also between black and white. Where there were more than 60% of observers choosing a particular dress as bigger the results have been highlighted. This percentage has been chosen as it shows a clear majority of either left or right.

For the purposes of evaluation all the images are identified with a letter (see Figure 5.10).

[1a] [1b] [1c] [1d] [1e] [1f] [1g] [1h]

Figure 5.10 – Dresses for BOS Survey No 1

The following points are evaluated:

1. Did the discrepancy in wording make a difference to the results?

In the first published survey there were discrepancies in the way the questions were worded. Questions 2,3 and 5 asked “WHICH LOOKS BIGGER?” and the rest of the questions all asked “WHICH IS BIGGER?” This difference in wording may have caused an issue with the way in which people answered and indeed was picked up in some of the feedback emailed to the researcher by a small number of observers. This is further discussed later in this section. The survey had been trialled before launching but this discrepancy was not picked up at that time and has therefore been attributed to human error. The difference that the wording made was perhaps more significant for results of

the second survey discussed in 5.4.2. The discrepancy in wording was noted and corrected in surveys 3 and 4.

2. What is different about the pairs that yielded an above average or clear majority result?

All the results that gave a more than 60% response have been highlighted above in Table 5.1. The designs which yielded the clearest result were dresses [1a] and [1e] which in all but one pair were chosen as the dress which looked or was bigger. Dresses [1a] and [1e] were the same monochromatic optical pattern (Wundt illusion) in [1a] white and [1e] black. This seems to show that when observers were shown the Wundt illusion on a white or black dress next to the Herring illusion on a white or black dress as seen in [1b],[1c],[1d],[1f],[1g] and [1h], they observed that the Wundt illusion appeared bigger in all but one instance (question 13 being the exception). The other notable result was that in this survey observers chose a majority of black dresses as being bigger than white dresses which contradicts popular belief. However, this could be due to the fact that there is a light shadow bouncing off the side of the black dresses which could make them appear smaller than the white dresses which have a dark shadow bouncing off their sides. This supports Stevens' (2009) and Braddick's (1995) research discussed in 3.4.1. This is discussed again in point 3 and 6 below.

3. Does placement/monochromatic optical pattern make a difference?

The Herring illusion is presented in 3 placements on the dress, top [1c] and [1h], middle [1d] and [1g], and bottom [1b] and [1f]. In all but 3 occasions dresses [1c] and [1h] were chosen as the smallest where the illusion was concentrated at the top of the dress. The Wundt Illusion is presented in a central location on the dress and in white [1a], and black [1e]. Dress [1e] is consistently chosen by observers as appearing to be the biggest. This result could again indicate that the light shading on the sides of the dress changes the viewer's perception and therefore the black dress is chosen as appearing bigger than the white dress. Later experiments tested this theory. In all but

one case, the dresses that were presented with the Wundt illusion were chosen as appearing bigger than the dresses that had the Herring illusion.

4. Does pairing of white/white, black/black, black/white make a difference?

When white with white dresses are paired the dress that is chosen most frequently as being bigger is dress [1b] with the Herring illusion placed on the bottom of the dress. On no occasion is dress [1c] chosen where the Herring illusion is placed at the top of the dress. When black with black dresses are paired, dress [1e] with the Wundt illusion in white is chosen three out of three times. The Herring illusion configurations on black pairs were not tested in this survey. This was an oversight on the part of the researcher but was not deemed to be significant enough to be tested further as more significant results led the research in another direction (the shadow on the sides of the dresses).

When black dresses were compared to white dresses there was a 50/50 split in the results. Out of 16 black and white pairs 8 of the black dresses were perceived as being bigger and 8 of the white dresses were perceived as being bigger. Dress [1e] the Wundt illusion presented on a black dress was chosen every time, on 4 occasions, by a significant amount of observers as appearing as bigger. Dress [1a] the Wundt illusion presented on a white dress was only chosen twice out of a possible of 4 times. Dress [1d] the white dress with the Herring illusion presented on the middle of the dress was chosen 3 times as appearing bigger to the observers.

In all combinations the Wundt illusion is perceived as bigger regardless of being paired white with white, black with black or white with black. The Herring illusion when presented on the middle of the dress when not next to the Wundt illusion is perceived as being bigger the most number of times regardless of what colour it is paired with.

5. Are images on left or right chosen more frequently as bigger/ smaller?

Research shows that shoppers tend to go left when entering a store and naturally shop in an anti-clockwise direction (Sorensen, 2009) and (Andrews,

1989) Would this phenomenon be translated into how people make choices when presented with visual information in surveys?

The images on the left were chosen on 13 occasions and the images on the right were chosen on 12 occasions. This implies that on this occasion it made no difference whether the images were presented on the left or the right.

6. Does shading make a difference?

According to the Helmholz square, irradiation effect, where white on black will appear larger than black on white, it was expected that the white dress would be chosen as bigger over the black dress every time. In this survey there was a clear split between the black and white being chosen. The light shading on the black dress at the sides may have given the observer the illusion that the black dress was bigger and the dark shadows on the white dress may have made the white dress look smaller. All dresses were presented on a white background. Therefore this could have created the irradiation effect when black was next to white. An unexpected result was that on several occasions the white dress was chosen as smaller than the black dress. This could be attributed to the dark shading on the white dress at the edges and the light shading on the black dress at the sides. This effect and possible theory is explored further in later surveys and is discussed again in Section 5.4.3.

7. Does the number of observers for each survey make a difference?

The number of observers that completed the first survey was 305 out of a sample of 401 who started the survey. This was a completion rate of 76%. The sample consisted of the people who followed the link to BOS from the invitation e-mail. This will be compared to results in later surveys and a conclusion will be drawn.

8. Is the number of unfinished surveys significant in terms of the survey success: Does it tell you something about ideal length of survey etc.

Survey No 1 had 305 completed results and 96 incomplete. The survey length was 25 questions. Although Observers were asked to give their first impressions (detailed in the email which was sent with the survey to all participants) it was clear from feedback that observers were taking longer than the recommended time (5 minutes) to complete the surveys. This indicated that the survey might be too long, as almost one quarter of all participants did not complete.

9. Evaluate observer comments.

The comments made by observers for BOS No 1 were similar for all those that gave feedback. The overall comment was that the survey was interesting and enjoyable to complete and that it presented an interesting challenge in deciding which dress appeared bigger. Another comment was that there were discrepancies in the wording. The wording was changed for the 3rd and 4th surveys.

5.4.2 *Bristol Online Survey No 2 – Which is Bigger/Same?*

In the 2nd survey built using BOS a selection of Projected Pattern Dresses (PPD) were arranged in pairs in combinations of the different 8 designs in black and white. All the white dresses were also presented as black dresses by inverting white to black in Adobe Photoshop.

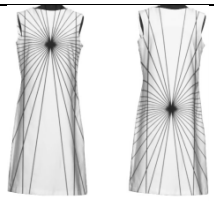
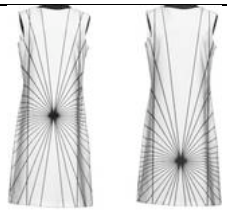
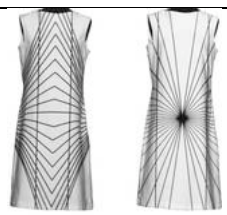
There were 25 pairs made of combinations out of a total of 4 black designs on a white dress and 4 white designs on black dress (inverted from the white designs using Adobe Photoshop). All the dresses were exactly the same size; the only differences were the design projected onto each dress and whether the dress was black or white.

The 2nd survey, named 'Which is Bigger/Same?' was launched on 03/11/2009 and results were collected up until 03/12/09. Observers were contacted

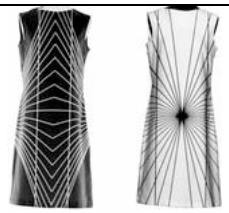
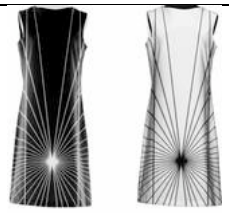
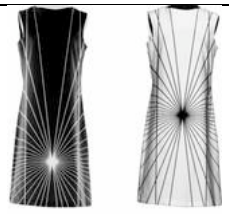
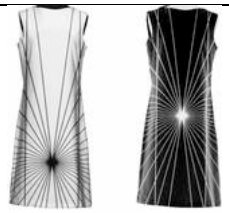
through Heriot Watt University, School of Textiles and Design's webmail via a link in an email and the survey was also sent to a sample of contacts throughout the UK covering a large demographic. Out of a total of 168 responses to the 'Which is Bigger/Same?' survey 120 observers completed the survey and there were 48 incomplete surveys. This gave a completed survey rate of 71.4%.

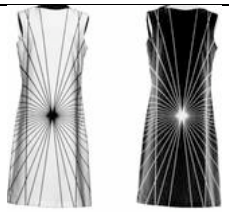
The 2nd survey was an exact copy of the 1st survey where all dresses were the same size but there was the option to choose 'same', which was not available in the 1st survey.

The pairs of dresses and the results can be seen in the table below (Table 5.2).

1	WHICH IS BIGGER?		Left 11.7% 14	Right 58.3% 70	Same 30.0% 36
2	WHICH LOOKS BIGGER?		Left 10.8% 13	Right 62.5% 75	Same 26.7% 32
3	WHICH LOOKS BIGGER?		Left 28.3% 34	Right 44.2% 53	Same 27.5% 33
4	WHICH IS BIGGER?		Left 21.7% 26	Right 50.0% 60	Same 28.3% 34
5	WHICH LOOKS BIGGER?		Left 41.7% 50	Right 36.7% 44	Same 21.7% 26

6	WHICH IS BIGGER?		Left 27.5% 33	Right 35.8% 43	Same 36.7% 44
7	WHICH IS BIGGER?		Left 35.8% 43	Right 30.0% 36	Same 34.2% 41
8	WHICH IS BIGGER?		Left 32.5% 39	Right 35.8% 43	Same 31.7% 38
9	WHICH IS BIGGER?		Left 20.0% 24	Right 47.5% 57	Same 32.5% 39
10	WHICH IS BIGGER?		Left 28.3% 34	Right 25.0% 30	Same 46.7% 56
11	WHICH IS BIGGER?		Left 47.55 57	Right 25.8% 31	Same 26.7% 32
12	WHICH IS BIGGER?		Left 45.0% 54	Right 21.7% 26	Same 33.3% 40
13	WHICH IS BIGGER?		Left 29.2% 35	Right 36.7% 44	Same 34.2% 41

14	WHICH IS BIGGER?		Left 17.5% 21	Right 45.8% 55	Same 36.7% 44
15	WHICH IS BIGGER?		Left 31.7% 38	Right 33.3% 40	Same 35.0% 42
16	WHICH IS BIGGER?		Left 28.3% 34	Right 36.7% 44	Same 35.0% 42
17	WHICH IS BIGGER?		Left 4.2% 5	Right 47.5% 57	Same 48.3% 58
18	WHICH IS BIGGER?		Left 6.7% 8	Right 65.8% 79	Same 27.5% 33
19	WHICH IS BIGGER?		Left 16.7% 20	Right 41.7% 50	Same 41.7% 50
20	WHICH IS BIGGER?		Left 26.7% 32	Right 31.7% 38	Same 41.7% 50
21	WHICH IS BIGGER?		Left 15.0% 18	Right 56.7% 68	Same 28.3% 34

22	WHICH IS BIGGER?		Left 32.5% 39	Right 18.3% 22	Same 29.2% 59
23	WHICH IS BIGGER?		Left 15.8% 19	Right 26.7% 32	Same 57.5% 69
24	WHICH IS BIGGER?		Left 12.5% 15	Right 66.7% 80	Same 20.8% 25
25	WHICH IS BIGGER?		Left 12.5% 15	Right 57.5% 69	Same 30.0% 36

(Table 5.2 - Bristol Online Survey No 2 – Which is Bigger/Same?)

Where there were more than 40% of observers choosing a particular dress as bigger the results have been highlighted. This percentage has been chosen, as it shows that an above average number of observers made this choice.

For the purposes of evaluation all the images are identified with a letter detailed below. (see Figure 5.11)

[2a] [2b] [2c] [2d] [2e] [2f] [2g] [2h]

Figure 5.11 – Dresses for survey no 2

The following points are evaluated:

1. Did the discrepancy in wording make a difference to the results?

In the 1st published survey there were discrepancies in the way the questions were worded and as the wording of the questions of the 2nd published survey was an exact copy of the 1st these discrepancies remained. The wording of the title of the second survey now had the word 'Same' added and observers had the option to choose left, right or same. Questions 2,3 and 5 asked "WHICH LOOKS BIGGER?" and the rest of the questions all asked "WHICH IS BIGGER?" There was no mention in each of the twenty-five questions about the 'same' option although it was one of the boxes that could be chosen. This difference in wording may have caused an issue with the way in which people answered and indeed was picked up in some of the feedback emailed to the researcher by a small number of observers, this is discussed in point 9. The discrepancy in wording was noted and corrected in surveys 3 and 4.

2. What is different about the pairs that yielded an above average or clear majority result?

All the results that gave a more than 40% response have been highlighted above in Table 5.2. The designs that yielded the biggest response were dresses [2a] and [2d] and 'same' was chosen as most popular on six occasions out of twenty-five possible answers. Dresses [2a] and [2d] were both white dresses. Dress [2a] had the Wundt illusion and dress [2d] had the Herring illusion presented in the middle position on the dress. When dress [2a] was paired with both white and black dresses it was chosen as bigger on four occasions out of a possible seven. Dress [2a] was chosen as 'same' on one occasion when paired with dress [2e] which was the black dress also presented with the Wundt illusion. Dresses [2c] and [2h] were consistently chosen as the smallest dress on eight occasions out of a possible eleven. On one occasion an equal number of participants perceived dress [2c] to be either bigger or the same as dress [2f]. Dresses [2h] and [2b] were perceived as the same, and dresses [2h] and [2c] were perceived as the same.

3. Does placement/monochromatic optical pattern make a difference?

The Herring illusion is presented in 3 placements on the dress, top [2c] and [2h], middle [2d] and [2g], and bottom [2b] and [2f]. In all but one occasion dresses [2c] and [2h] were chosen as smaller where the illusion was concentrated at the top of the dress. The Wundt Illusion is presented in a central location on the dress and in white [2a], and black [2e]. Dress [2a] is chosen by observers as appearing bigger on four occasions. When dresses [2a] and [2e] are paired they had a majority of observers perceiving them as the same. When dresses [2f] and [2b], where the Herring illusion is presented at the bottom of the dress they were perceived a majority of the time as the same. When dresses [2h] and [2c] where the Herring illusion is presented at the top of the dress the majority of observers perceived them as the same. Overall the dresses that were presented with the Wundt illusion were chosen as appearing bigger than the dresses that had the Herring illusion. When the Herring illusion is presented on both the black and white dresses they are perceived as smaller when next to other placements every time apart from when perceived as the same on three occasions out of eleven.

4. Does pairing of white/white, black/black, black/white make a difference?

When white with white dresses are paired the dress that is chosen most frequently as being bigger is dress [2b] with the Herring illusion placed on the bottom of the dress. On no occasion is dress [2c] chosen where the Herring illusion is placed at the top of the dress and on no occasion is there a majority of observers choosing Same. When black with black dresses are paired, dress [2e] with the Wundt illusion in white is chosen two out of three times. When the Wundt illusion on a black dress is compared to the black dress with Herring illusion presented at the bottom [2f], there is a slight majority towards dress [2f]. The Herring illusion configurations on black pairs were not tested in this survey. This was an oversight on the part of the researcher but was not deemed to be significant enough to be tested further as more significant results led the research in another direction (the shadow on the sides of the dresses).

When black dresses were compared to white dresses there was a significant split between results. Out of sixteen black and white pairs, eight of the white dresses were perceived as being bigger and four of the black dresses were perceived as being bigger. Four pairs of dresses were perceived as the same. Dress [2e] the Wundt illusion presented on a black dress was chosen on three occasions, by a small majority of observers as appearing as the biggest. Dress [2a] the Wundt illusion presented on a white dress was chosen two times out of a possible four.

Same was chosen six times out of a possible sixteen times when dresses were paired with either black or white. On three occasions this same result was perceived when the same illusion on the same position on the dress was presented. This happened with pairs, [2a] and [2e], [2f] and [2b] and pairs [2h] and [2c].

5. Are images on left or right chosen more frequently as bigger/ smaller?

The images on the left were chosen on five occasions as bigger and the images on the right were chosen as bigger on thirteen occasions. The images that were chosen as Same were chosen seven times. If people shopping habits and natural tendency to go left when shopping/entering a store is relevant when people are given a choice of left or right in a visual survey, then the results of this question outlined above disprove Sorensen' (2009) and Andrews' (1989) evidence on this occasion.

6. Does shading make a difference?

As mentioned in section 5.4.1 point 6, the Helmholz square, irradiation effect, where white on black will appear larger than black on white it was expected that the white dress would be chosen as bigger over the black dress every time. However in this survey there was a clear split between the black and white being chosen. The light shading on the black dress at the sides may have given the observer the illusion that the black dress was bigger and the dark shadows on the white dress may have made the white dress look smaller. All dresses were presented on a white background. Therefore this could have

created the irradiation effect when black was next to white. An unexpected result was that on several occasions the white dress was chosen as smaller than the black dress. This could be attributed to the dark shading on the white dress at the edges and the light shading on the black dress at the sides. This effect and possible theory is explored further in later surveys and discussed in 5.4.3.

7. Does the number of observers for each survey make a difference?

This survey had fewer observers than Survey no 1 but was presented with the same images in the same order with the difference being that the option "Same" was there. It is difficult to say if it makes a difference to the results. However, when comparing results there is a similar trend towards what observers choose as being bigger between the same surveys. The difference between the surveys was that observers had the option to choose "Same". These results indicate that the sample size was sufficient to yield a similar result as survey 1 achieved.

8. Is the number of unfinished surveys significant in terms of the survey success?

It was noted that there was a significant drop in the amount of observers taking part in the 2nd survey. Observer comments were that it was the same survey that they had just done (survey 1) and that they did not believe that it was a different survey. It was concluded that the researcher did not make the survey appear different enough from the 1st survey and that it was sent out too soon after the 1st survey with a similar appearance, leading participants to believe that they had already completed it. Although the response rate was high for completed surveys out of surveys started (above 70% in both survey 1 and 2), it was deemed that the survey was too long after reviewing observers' comments.

9. Evaluate observer comments.

The comments made by observers for BOS No 2 were similar for all those that gave feedback and similar comments to those given for BOS No1. The overall comment was that the survey was interesting and enjoyable to complete and that it presented an interesting challenge in deciding which dress appeared bigger. Another comment was that there were discrepancies in the wording. The wording was changed for the 3rd and 4th surveys. Two observers made the comment that they had just completed this survey as they did not notice that there was a choice of answers that were different from
BOS No1.

10. Does the addition of same affect the results

Comparing BOS Survey 1 and 2, the addition of same made a significant difference in BOS Survey 2 in pairs 6, 10, 15, 17, 19, 20 and 23. In Pairs 10, 20 and 23, 10% or more of observers chose the same option over a left or right answer. In pairs 10, 20 and 23 in BOS survey 1, there was no more than 10% difference between a choice of left or right. This meant that the observers were not able to see a difference in these pairs and that in BOS survey 1 the results were split between left and right almost evenly.

5.4.3 *Summary for Surveys 1 and 2*

In surveys 1 and 2 unnatural shadows were created on the black dresses when they were inverted in Adobe Photoshop from white to black. This unnatural shadow could have been the reason why some of the black dresses were chosen as bigger than the white dresses on some occasions. Therefore a third survey was constructed to investigate the results of putting black and white dresses on white, black and grey backgrounds.

A main outcome of surveys 1 and 2 was that a dress with the Wundt illusion was almost always chosen as bigger by observers.

5.4.4 *Bristol Online Survey No 3 – Black and White?*

In the 3rd survey built using BOS a selection of plain black and white dresses were arranged in pairs to exhaust all combinations of black and white dresses together presented on either the left or the right and on three different backgrounds, white, black and grey. All the white dresses were presented as black dresses by inverting white to black in Adobe Photoshop. This method was used to detect whether the inverted shadow created when inverting from white to black would affect how the dresses were perceived. The different backgrounds were used to investigate further the Helmholtz irradiation effect. There were twelve pairs made of combinations of black and white dresses presented on white, black and grey backgrounds in both left and right positions. Questions were also posed as Left or Right for a forced answer and Left, Right or Same?

The 3nd survey, named 'Black and White?' was launched on 10/12/2009 and results were collected up until 10/01/2010. Observers were contacted through Heriot Watt University, School of Textiles and Design's webmail via a link in an email and the survey was also sent to a sample of contacts throughout the UK covering a large demographic. Out of a total of 220 responses to the 'Black and White?' survey 202 observers completed the survey and there were 18 incomplete surveys. This gave a completed survey rate of 91.8%.

The pairs of dresses and the results can be seen in the table below (Table 5.3).

1	WHICH APPEARS BIGGER?		Left 47.0% 95	Right 53.0% 107	
2	WHICH APPEARS BIGGER?		Left 33.2% 67	Right 33.2% 67	Same 33.7% 68

3	WHICH APPEARS BIGGER?		Left 27.7% 56	Right 72.3% 146	
4	WHICH APPEARS BIGGER?		Left 35.1% 71	Right 22.8% 46	Same 42.1% 85
5	WHICH APPEARS BIGGER?		Left 28.7% 58	Right 43.1% 87	Same 28.2% 57
6	WHICH APPEARS BIGGER?		Left 69.8% 141	Right 30.2% 61	
7	WHICH APPEARS BIGGER?		Left 24.8% 50	Right 36.1% 73	Same 39.1% 79
8	WHICH APPEARS BIGGER?		Left 45.5% 92	Right 54.5% 110	
9	WHICH APPEARS BIGGER?		Left 19.8% 40	Right 58.9% 119	Same 21.3% 43
10	WHICH APPEARS BIGGER?		Left 55.4% 112	Right 44.6% 90	

11	WHICH APPEARS BIGGER?		Left 41.6% 84	Right 58.4% 118	
12	WHICH APPEARS BIGGER?		Left 55.4% 112	Right 19.3% 39	Same 25.2% 51

Table 5.3 - Bristol Online Survey No 3 – Black and White?

Where there were more than 40% of observers choosing a particular dress where there is also the 'same' option the result has been highlighted. Where there were more than 60% of observers choosing a particular dress as bigger when there was only a Left or Right option, the results have been highlighted. These percentages have been chosen, as it is shows that an above average amount of observers chose these dresses.

The following points were evaluated:

1. Did the difference in wording in Survey 3 make a difference to the results?

After the wording discrepancies in Surveys 1 and 2 were picked up the wording for Survey 3 was changed to 'WHICH APPEARS BIGGER?'. This gave the observers more of an indication that they were to choose what they perceived as bigger rather than to deliberate over what WAS bigger. Comments received from the observers indicated that this change was received favourably.

2. What is different about the pairs that yielded an above average or clear majority result?

The most significant finding from the results of Survey no 3 was that the white dress was chosen on eight occasions out of a possible of twelve occasions as bigger. The combinations of dresses had a majority of 'Same' choices on three

occasions, twice on a white background and once on a black background. The black dress was chosen as bigger on only one occasion. Even though the black dress was presented with light shadows on the edges it only appeared as bigger on one occasion and this was on a black background. This was an unexpected result as the Helmholtz irradiation effect suggests that white overflows onto a black background and black recedes. It was expected that observers would choose the black dress with light shadows at the edges on darker backgrounds as bigger on more occasions than was recorded. This initial experiment looking at black and white dresses supports the common belief that white makes you look bigger and black makes you look smaller.

3. Does the background make a difference?

When the black and white dresses were presented on the grey background there was a bigger difference in result than when presented on either black or white. On no occasion when the dresses were on grey did the majority of observers choose the same option. When the dresses were presented on a white background the results were more evenly split veering towards a ‘Same’ result on all occasions whether there was an option for same or not.

4. Are images on left or right chosen more frequently as bigger/ smaller?

All dresses were presented in either, left and right and right and left, and were also presented with the option of ‘Left’ or ‘Right’ and ‘Left’ or ‘Right’ or ‘Same’. On six occasions ‘Right’ was chosen. On three occasions Left was chosen and on three occasions three occasions ‘Same’ was chosen. The white dress was chosen six times when it appeared on the right and the black dress was chosen only once when it was on the right. The white dress was also chosen three times when it appeared on the left. On two occasions where the dress appeared on the left once on a grey background and once on a white background the Same was chosen.

5. Does shading make a difference?

In Survey 3 the shading on the dress did not appear to make a difference to how the observer perceived the dress. In only one occasion the black dress was chosen as bigger than the white dress when presented on a black background. This is the result that was expected for all of the black dresses that were presented on a dark background due to the light shadows on their edges. When compared to results from surveys 1 and 2 where the Black dresses with monochromatic optical patterns projected onto them were perceived as bigger than the white dresses with monochromatic optical patterns projected onto them, the observations from Survey 3 did not give similar results. The white dresses were chosen as bigger on all but four occasions out of twelve occasions.

6. Does the number of observers for each survey make a difference?

It was not possible to tell at this point whether or not the number of respondents made a difference to the results of this survey or not as there is one more survey to complete. This question will be answered later in this Chapter

7. Is the number of unfinished surveys significant in terms of the survey success: Does it tell you something about ideal length of survey etc.

Due to the fact that 202 observers completed Survey no 3 out of 220 respondents shows that the length and format of the survey was a success. This gave a 91.8% completion rate for this survey. As this was a very high response rate this survey is deemed as a good length and format to encourage most participants to complete.

5.4.5 *Discussion of results for Surveys 1,2 and 3*

One major finding that has been discovered is that when the black dresses and the white dresses have the Wundt and Herring patterns projected onto them significantly different results occurred than when there was no pattern on them. In survey 1 the black dress with a projected optical pattern was chosen a

majority of times however in survey 3 which had been devised to test this result, the black dress was only chosen as bigger on one occasion which is an opposite result from survey 1. This result suggests that the application of monochromatic optical pattern has made a difference to how the dress is perceived.

The black dresses that had the Wundt illusion presented on them in Survey 1 were consistently chosen as being bigger. This was thought to be attributed to the light shading on the side of the dress and not entirely due to the monochromatic optical pattern. However when the black dress with the same shading but no monochromatic optical pattern was tested in Survey 3 the same results did not occur. In only one occasion was the black dress chosen and this was when it was presented on a black background (see Table 5.3, Question 8).

Another significant finding was the position of the Herring illusion. Both Survey no 1 and Survey no 2 showed a majority result when the Herring illusion was presented at the bottom or the middle position on the dress. This meant that in all but two cases in both surveys, the Herring illusion presented this way was perceived as being bigger.

In an iterative process, these 1st three surveys tested methods and designs which informed the final survey design. Of the people who responded to all three surveys there was a high completion rate, which made the results richer and more valid. It was important that the format of the final survey achieved the most scientific results possible, so it followed the principles of good survey design. Like the first three surveys, the final survey used a convenience sample of respondents who self selected through an open invitation.

5.5 Bristol Online Survey Number 4 – What is your perception?

In the 4th and final survey built using BOS a selection of Projected Pattern Dresses (PPD) were arranged in pairs in combinations of the different 8 designs in black and white. All of the black dresses were also presented as white dresses by inverting black to white in Adobe Photoshop. This was done

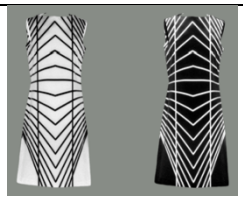
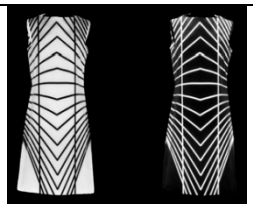
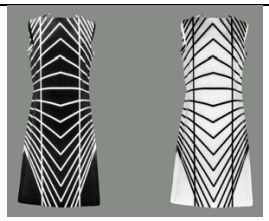
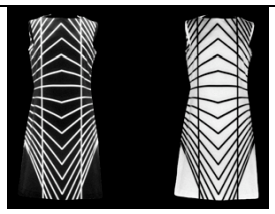
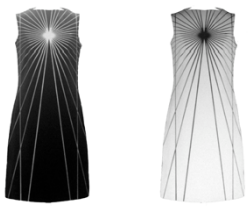
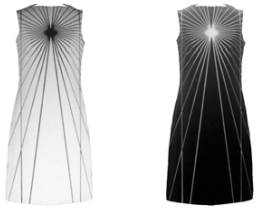
to see whether a difference could be detected when the shadows were in a different place than when a white dress was inverted to become a black dress. The combinations of black and white dress that were missed out in survey 1 were also explored although with different shading on the dresses than had been present in surveys 1 and 2.

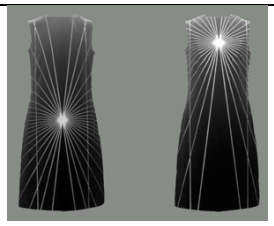
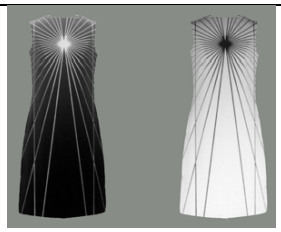
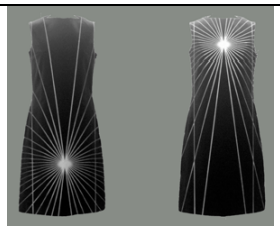
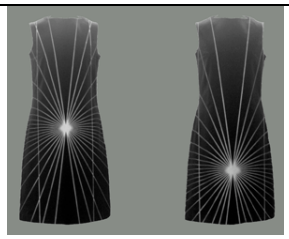
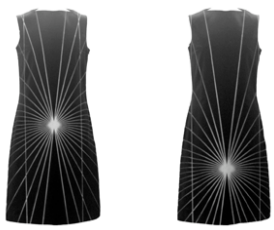
There were 27 pairs made of combinations out of a total of 4 white designs on a black dress and 4 black designs on a white dress (inverted from the black designs using Adobe Photoshop). All the dresses were exactly the same size; the only differences was the design projected onto each dress and whether the dress was black or white.

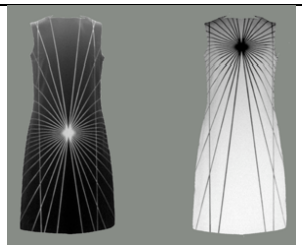
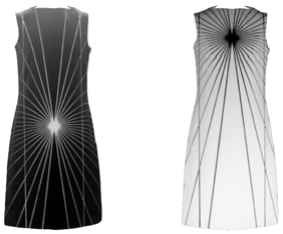
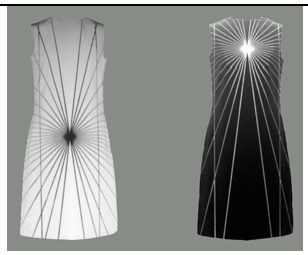
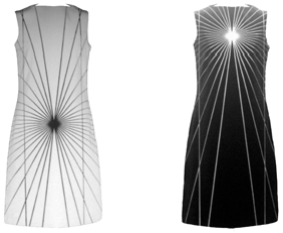
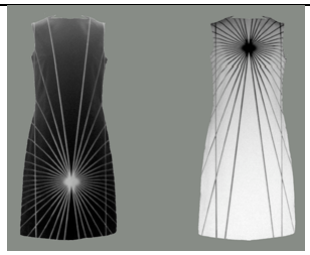
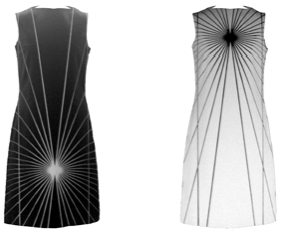
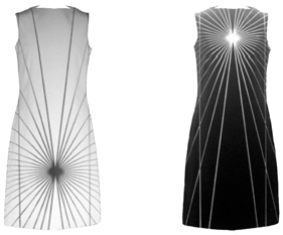
The 4th survey, named 'What is your perception?' was launched on 10/07/2010 and results were collected up until 10/09/2010. Observers were contacted through Heriot Watt University, School of Textiles and Design's webmail via a link in an email and the survey was also sent to a sample of contacts throughout the UK covering a large demographic via email. Out of a total of 418 responses to the 'What is your perception?' survey 235 observers completed the survey and there were 183 incomplete surveys. This gave a completed survey rate of 56%. It has been concluded that the number of incomplete surveys was due to the length of survey and the time that respondents took to complete the survey. Also the fact that there was no option for respondents to save the survey part way through and complete it later. Therefore it was assumed that a number of respondents may have started the survey and not completed it and therefore had to start the survey from the beginning again to complete it. There was still a significant number of completed surveys which gave enough completed surveys for a reasonable result.

The 4th survey was based on the 1st survey where all dresses were the same size and there was only the option to choose either left or right. There was no option for same in this survey. This produced a forced choice answer where observers were forced to make a choice about one being bigger than the other and therefore were unable to sit on the fence with their answers.

The pairs of dresses and the results can be seen in the table below (Table 5.4).

1	WHICH LOOKS BIGGER?		LEFT 69.4% 163	RIGHT 30.6% 72
2	WHICH LOOKS BIGGER?		LEFT 66.8% 157	RIGHT 33.2% 78
3	WHICH LOOKS BIGGER?		LEFT 35.7% 84	RIGHT 64.3% 151
4	WHICH LOOKS BIGGER?		LEFT 49.8% 117	RIGHT 50.2% 118
5	WHICH LOOKS BIGGER?		LEFT 33.2% 78	RIGHT 66.8% 157
6	WHICH LOOKS BIGGER?		LEFT 23.8% 56	RIGHT 76.2% 179
7	WHICH LOOKS BIGGER?		LEFT 35.7% 84	RIGHT 64.3% 151
8	WHICH LOOKS BIGGER?		LEFT 49.4% 116	RIGHT 50.6% 119

9	WHICH LOOKS BIGGER?		LEFT 73.6% 173	RIGHT 26.4% 62
10	WHICH LOOKS BIGGER?		LEFT 69.4% 163	RIGHT 30.6% 72
11	WHICH LOOKS BIGGER?		LEFT 34.5% 81	RIGHT 65.5% 154
12	WHICH LOOKS BIGGER?		LEFT 60% 141	RIGHT 40% 94
13	WHICH LOOKS BIGGER?		LEFT 51.9% 122	RIGHT 48.1% 113
14	WHICH LOOKS BIGGER?		LEFT 49.4% 116	RIGHT 50.6% 119
15	WHICH LOOKS BIGGER?		LEFT 44.7% 105	RIGHT 55.3% 130

16	WHICH LOOKS BIGGER?		LEFT 51.9% 122	RIGHT 48.1% 113
17	WHICH LOOKS BIGGER?		LEFT 53.6% 126	RIGHT 46.4% 109
18	WHICH LOOKS BIGGER?		LEFT 69.8% 164	RIGHT 30.2% 71
19	WHICH LOOKS BIGGER?		LEFT 70.2% 165	RIGHT 29.8% 70
20	WHICH LOOKS BIGGER?		LEFT 43.8% 103	RIGHT 56.2% 132
21	WHICH LOOKS BIGGER?		LEFT 40.9% 96	RIGHT 59.1% 139
22	WHICH LOOKS BIGGER?		LEFT 59.6% 140	RIGHT 40.4% 95

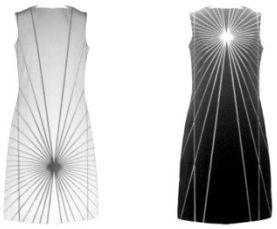
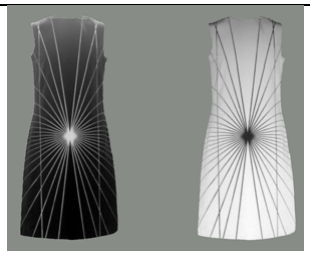
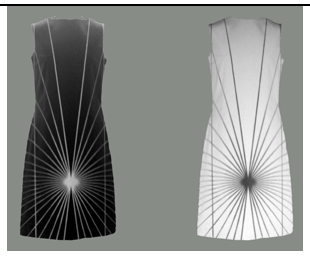
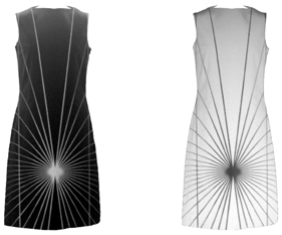
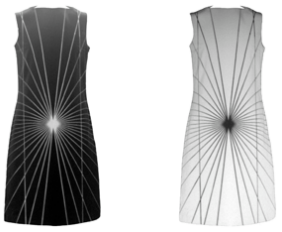
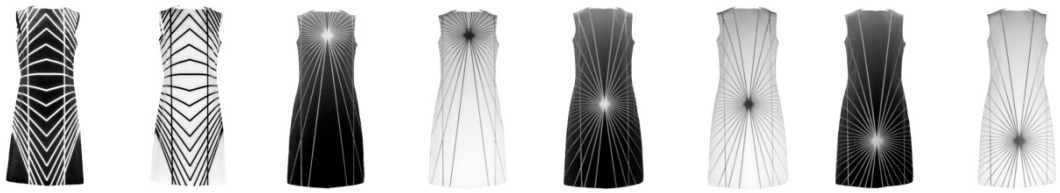
23	WHICH LOOKS BIGGER?		LEFT 61.3% 144	RIGHT 38.7% 91
24	WHICH LOOKS BIGGER?		LEFT 29.8% 70	RIGHT 70.0% 165
25	WHICH LOOKS BIGGER?		LEFT 29.8% 70	RIGHT 70.2% 165
26	WHICH LOOKS BIGGER?		LEFT 29.4% 69	RIGHT 70.6% 166
27	WHICH LOOKS BIGGER?		LEFT 26% 61	RIGHT 74% 174

Table 5.4 - Bristol Online Survey Number 4 – What is your perception?

The results showed some differences observed between optical patterns and also between black and white. Where there were more than 60% of observers choosing a particular dress as bigger the results have been highlighted.

For the purposes of evaluation all the images are identified with a letter (see Figure 5.12).



[4a] [4b] [4c] [4d] [4e] [4f] [4g] [4h]

Figure 5.12 – Dresses for BOS Number 4

The following points are evaluated:

1. Did the discrepancy in wording make a difference to the results?

After the wording discrepancies in Surveys 1 and 2 was picked up the wording for Survey 4 was changed to 'WHICH LOOKS BIGGER?'. This was different again from the wording that was in Survey 3 which was 'WHICH APPEARS BIGGER?'. This gave the observers an indication that they were to choose what they perceived as bigger rather than to deliberate over what WAS bigger. There were no comments from respondents regarding this change and therefore it was deemed to be acceptable and give desired results.

2. What is different about the pairs that yielded an above average or clear majority result?

All the results that gave a more than 60% response have been highlighted above in Table 5.4. The most notable result was that in this survey observers chose white dresses as being bigger than black dresses on all but four occasions when black and white dresses were paired together, which contradicts results from survey one. This result could be due to the fact that the light shadow bouncing off the side of the dresses was corrected from survey 1 as the black dresses were true photographs of black dresses rather than white dresses that had been inverted to become black dresses in Photoshop. This is discussed further in point 6. The designs which yielded the clearest result were dresses [4b], [4d], [4e], [4f], [4g] and [4h]. Dresses [4b], [4d], [4f] and [4h] were all white either with the Wundt illusion or the Hering illusion projected onto them in three different positions, top, middle or bottom. Dress [4b] had over 60% of respondents choosing it as bigger five times out of

a possible six. On the one occasion that dress [4b] did not yield more than 60% choice rate it was chosen as bigger by only 49.6% of observers. Even though in this experiment the white dresses had been produced in Adobe Photoshop by inverting the photographed black dresses they were still chosen as looking bigger. This result is surprising as they had dark shadows at the sides and this would tend to make them appear smaller according to literature researched and discussed in Chapter 3.

3. Does placement/monochromatic optical pattern make a difference?

The Herring illusion is presented in 3 placements on the dress, top [4c] and [4d], middle [4e] and [4f], and bottom [4g] and [4h]. Echoing results seen in Survey one in all but 5 occasions dresses [4c] and [4d] were chosen as the smallest where the illusion was concentrated at the top of the dress. The Wundt Illusion is presented in a central location on the dress and in white [4b], and black [4a]. Dress [4b] is consistently chosen by observers as appearing to be the biggest. This result could indicate that as the dress is white it fits in line with common fashion beliefs that white will make you look bigger. However, this result contradicts results seen in survey 1 where the black dress with the Wundt illusion was consistently chosen as bigger. The results for survey 4 where the shadows have been reversed show that when the true shadow is shown the white dress is indeed perceived as looking bigger than the black dress. This phenomenon is occurring even though the white dress has an inverted shadow thus suggesting that even this will not shrink the appearance of white.

4. Does pairing of white/white, black/black, black/white make a difference?

In survey 4 only the black dresses with the Hering illusion were paired with black dresses as these combinations had not been explored in surveys 1 and 2. All other combinations were with a black and a white dress and all combinations of Hering pattern together was explored. However it was noted that the pattern yielded a significant result as did either the white or the black dress. Conclusions were made that the white dress was perceived as looking bigger more often than the black dress however when a certain pattern was present it

was chosen as biggest or smallest regardless of whether it was paired with a white or black dress. This response was noted when the Hering illusion was presented at the top of the dress which was perceived as smaller even on a white dress paired with a black dress with the Hering illusion presented in a different position to top.

When two black dresses were presented next to each other the dress with the Hering illusion projected at the top of the dress [4c] was never chosen as biggest. The dress with the Hering illusion projected in the middle [4e] was chosen twice out of a possible four times when presented alongside the dress with the Hering illusion projected at the bottom of the dress [4g]. Dress [4g] was chosen four times out of a possible four times as being the biggest.

5. Are images on left or right chosen more frequently as bigger/ smaller?

The phenomenon discussed in survey 1, was looked at in the instance of these tests in case there was a tendency for observers to choose right over left. The paired dresses were arranged in a random order to alleviate this potential problem. The dresses on the left were chosen 12 times out of a possible 27. This meant that the dresses on the right were chosen as bigger more often with a score of 15 out of a possible 27. However, a white dress did appear on the right more often than on the left. This could have affected this conclusion. In question 3 when [4a] was presented on the left next to [4b] on the right on a white background, the right hand dress [4b] was chosen as bigger by 64.3% of observers. In the next question, question 4, the dresses were switched round so that the white dress was on the left and the black on the right and the result was very different. In question 4 the dresses were chosen by 49.8% of observers and 50.2% of observers showing an almost 50/50 split. So by transposing the dresses in these two questions a different result was observed.

6. Does shading make a difference?

In previous surveys the black dresses had been achieved by inverting the photographs of the white dresses using Adobe Photoshop. This appeared to give an unexpected result, black dresses were chosen as bigger more often

than white dresses were. In Survey 4 the shading of the white dresses was inverted as they had been produced using the photographs of the black dresses which were then inverted using Adobe Photoshop. This difference in shading meant that following the theories of the Helmholtz square, irradiation effect, that white would spill out and black would recede. It was expected that the result would be that with dark shading at the edges the white dresses would appear smaller and be picked less often than the black dress as being bigger. The white dresses were chosen 18 times out of a possible 21 times as being bigger than the black dresses. On one occasion the dress was on a grey background when chosen as smaller but on the other two occasions it was on a white background. This result reversed the findings in survey 1 where the white dress was chosen as smaller on more occasions than the black dress. This result suggests that shading at the side of the garment could dramatically change the viewer's perception.

7. Does the number of observers for each survey make a difference?

Survey number 4 was 27 questions long, a similar length to surveys 1 and 2 which were both 25 questions long. 408 recipients responded to the link and started the survey, 235 recipients completed the survey which gave a completion rate of 58%. The number of completed surveys was similar to the number of completed surveys in Survey 3 which had far fewer questions (12). It was not possible to tell at this point whether or not the number of respondents made a difference to the results of the survey. This question will be answered in 8 below.

8. Is the number of unfinished surveys significant in terms of the survey success?

Due to the number of incomplete surveys it has been concluded that the survey was once again too long. There was a higher number of completed surveys than survey 2 and survey 3 and this could be due to the length of time between surveys. Another possible reason for the amount of incomplete surveys could be that observers regarded the surveys as appearing too similar to one another. Great care was taken to inform the recipients that each survey was different and

that their responses were valuable. Some possible reasons for this are discussed in point 9.

9. Evaluate observer comments.

There were few comments from observers. The comments that were received were that they felt that they were repeating a test they had done before. It is possible that in these tests emerging expert testers were becoming familiar with the tests and therefore a different introduction or briefing would be needed for future tests.

Some commented that they wished to see colour. Some said that they were surprised by what they thought looked bigger. There were also a couple of observers that commented that they found it hard to tell a difference and so therefore they guessed the answers. This comment from only two recipients made the high number of completed surveys more important. The higher the number of completed surveys the greater the chance of being able to disregard observer responses that were just guesses. There was also a general consensus that the designs 'messed with' the observers' eyes after a while and it was difficult to just make a quick decision. This meant that for some participants the test took longer than they were advised to spend on it. This could have resulted in the high amount of unfinished surveys.

10. Does the background make a difference?

In BOS survey 4 there were some interesting results when the paired dresses were presented on different backgrounds. Dresses [4b] and [4a] were presented in the same way on white, black and grey backgrounds. On the black and grey backgrounds dress [4b] was chosen by 69.4% of observers on grey and 66.8% of observers on black. In question 4, dress [4b] was only chosen by 49.8% of observers when presented on a white background suggesting that when this pair of dresses is presented on a white background observers see less of a difference. However, when dress [4a] and [4b] are transposed on a white background as discussed in point 5 they yield a different result. In questions 1, 2, 3, 5, 6 and 7 the white dress [4b] is chosen by 64.3 –

76.2% of observers as bigger. The same phenomenon occurred with dresses [4c] and [4d]. In questions 7, 11, dress [4d] was chosen by 64.3% and 65.5% of observers as bigger than dress [4c] on a white and a grey background where the white dress [4d] was presented on the left. In question 8 where the white dress [4d] and the black dress 4[c] were transposed 50.6% of observers chose the black dress as biggest and 49.4% of observers chose the white dress as biggest suggesting that they saw the dresses as similar in size. There were no other significant differences when dresses were presented on different backgrounds.

5.6 Conclusion of results of experiments

The experiments described in this chapter were conducted as a result of the conclusions formed in Chapter 4. The purposes of the 4 surveys were to fully test the paired comparison method as a way of measuring observers' perception of size in a web based format in a fashion context.

As a high number of observers was needed to give reliable results it was concluded that a web based survey would be the best possible means of quickly achieving a high volume of participants. A simple paired comparison test using only pictures and a left or right answer was presented using Bristol Online Surveys. Unlike the tests performed in Chapter 4 the researcher was not present during the surveys as participants made their observations on their chosen computer screen through a link that was emailed to mailing lists through the researcher's own personal address book and to Heriot Watt students and staff. The survey was also circulated via email to Glasgow University Post Graduate students and published on Facebook through a link direct to the surveys. This method of contacting potential observers proved to be successful for the purposes of this research as between 120 and 305 observers completed the surveys.

The paired comparison method proved to be successful at establishing significant results in all 4 surveys that were presented.

Survey 1 showed that the Wundt illusion when presented on a white or black dress was chosen as bigger. A surprising result was that overall observers chose a black dress as bigger than a white dress. This result has been attributed to the fact that the black dresses in survey 1 had been inverted from the photographs of the white dresses using Adobe Photoshop and therefore where there should have been dark shadows at the edges there were light shadows which gave the appearance of light bouncing off the sides of the black dresses. This phenomenon was reversed in survey number 4. When the effect was reversed, (photographs were taken of black dresses with white pattern projected onto them and then to produce white dresses the photographs of black dresses were inverted using Adobe Photoshop to create white dresses) observers chose a majority of white dresses as being bigger than the black dresses. This was the expected result and falls in with common belief.

5.6.1 *Key outcomes*

The following key outcomes were evident:

- The importance of eliminating shadow effect which is a result of the Helmholtz Irradiation effect. When addressed, the black dresses were consistently chosen as smaller which proves the received wisdom that black creates a smaller female body image
- The expected result of the 2D effect of the vertical lines in the Hering and Wundt illusions was reversed when projected onto a 3D dress.
- Placement of the Hering illusion was significant in how the size of individual dresses was perceived.

The entire process was performed in an iterative manner and the results of each survey influenced the design of the next.

In Chapter 6 the results set out in Chapter 5 are discussed in further detail and suggestions are made for future work and possible collaborations.

Chapter 6 also describes the Digital Sketch Books where the visual outcome of the projected monochromatic optical pattern dresses used in this chapter have

been presented in such a way that the design process can be seen visually. This visual outcome of this research sits alongside the written work.

5.7 References

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Chapter 6 – Conclusions and Suggestions for Future Work

6.1 Measuring perception

Gregory (1998) asserted that perception occurs within the mind of the perceiver and is therefore invisible and inaccessible to others. During the course of this research a method has been developed to assess perception and to achieve some measurement of what is being perceived, namely by measuring the ability of a significant number of participants to gauge the effect of printed monochromatic optical pattern on the perceived size of the female form. The thesis describes the steps undertaken to establish a method for measuring these observers' perceptions of size difference; a design method for the purposes of generating designs; the survey design process undertaken so that observers could make choices in a constant environment; and, ultimately and finally, the effects which changes in monochromatic optical pattern placement on a monochrome dress have on the perception of size by the viewer.

It has been mentioned that although there is much written and discussed in modern media regarding the well used question 'Does my bum look big in this?', there has never been any rigorous scientific research to investigate this topic. Most of the discussion has taken place in commercial media and the only academic reference found was the work of Imai (1982), Sai et al (1998) sited in (Taya & Muira, 2007) and a brief abstract by Thompson (2007). Frith & Gleeson (2008) confirm the lack of literature concerning the dressed female form and discuss how clothing is used to camouflage or reveal depending on the state of mind of the wearer. They discuss the use of qualitative methods to find results, as the area of body image in connection to clothing is under-researched and under theorised, and claim that this is an unusual method in the field of body image. Their use of qualitative methods was used to capture a very specific audience whereas the qualitative and quantitative methods used in this research aimed to capture a broader and somewhat more spread out demographic. The Facebook demographic used, although not entirely random, hit an audience that was interested in such studies and topics. The university network used during this study was a specific demographic made up of educated individuals who were IT savvy and interested in philosophising. The

methods that were explored varied and therefore triangulation was achieved to produce robust results.

The common belief that wearing black makes you look smaller and white makes you look bigger was explored and conclusions were drawn from the results of these experiments. There was also an investigation into the application of optical illusions onto garments as prints/patterns and how these would affect the viewer's perception of the size of a the female form.

6.2 How were the aims of the research answered?

The first aim was to establish the current state of knowledge regarding the manipulation of human perception of female form and how this change in perceived size can be measured and quantified. Evidence was given in Chapter 1 that there was little previous scientific literature which dealt with pattern and perceived body size and therefore broad reading and understanding of psychological factors regarding body image and size were looked at. It was found that much of that literature focused on body image and eating disorders and not necessarily the different perceptions that printed patterns could achieve to the viewer. Due to this lack of relevant literature the decision was made to go back to first principles and examine the literature concerning optical illusion and camouflage by shading. Previous research which had looked at pattern and the perception of body size used known optical illusions to provide a basis for the visual research. Taya and Miura (2007) had used the Helmholtz striped square illusion to test their theories on a cylindrical object and cited Imai (1982) and Sai et al (1998) as using striped suits to test the theory in a fashion context. In this study the Wundt and Hering illusions were used as the starting point to create a monochromatic optical pattern that could be applied to clothing to test whether or not monochromatic optical pattern could change the perception of size of a clothed female form.

A second aim of the research was the search for a method which would allow perception to be reliably measured. An important initial finding of the research was that no matter how a visual test was presented, the observer used an informal paired comparison method when asked to make a size choice. It was

clearly concluded that paired comparison was used regardless of the way in which samples and imagery were presented to an observer and no matter how they were asked to perform a ranking or rating scale. This was established via a means of supervised size scale experiments which were described in detail in Chapter 4.

A new version of a rating scale was devised (Caltyre scale) in line with the 'grey scale' with a view to using this as a method of measuring size perception. Although the Caltyre Scale was not used as the final method, the process of developing this new rating method informed the next stage of the research. The observation that informal paired comparison method is used regardless of the instruction given by the researcher to the observer confirmed a hypothesis that this is a natural choice method amongst human beings. For example, when choosing only one item to purchase the choice is often made by comparing one option against another and eliminating those considered less suitable. This phenomenon is also found when making comparisons with visual cues.

Although the initial mainly scientific approach referred to above did not lend itself well to the design discipline and was subsequently rejected, the finding that participants tended to use paired comparison to make choices was important in informing the decision to use a more suitable iterative process involving tacit methods to create a collection and solid fashion based work that could then be tested. The results discussed in Chapter 5 proved that it was possible in the specific conditions of this investigation to distort reality through the medium of print and therefore trick or deceive the observer into believing that a garment/body is bigger or smaller than it actually is. Incidentally this study also gives more weight to the common belief that white makes you look bigger and black makes you look smaller.

A third aim of the research was to establish a new method, whereby designers or consumers have a tool or a 'key' which they could refer to, to enable them to produce/choose designs that were flattering to different female forms. As already stated, established optical illusions were used as a basis for the designs for this research. These were chosen for two reasons. The first was

an interest in whether a 2D effect could be transferred to a 3D form and second these illusions offered an aesthetic which suited this designer's style. The initial design trials allowed for consideration of the best method to achieve the research aims and led naturally on to the more pragmatic uniform approach. The final method is described below.

The Hering and Wundt illusions were projected onto plain white and black dresses and then photographed and the photographs were then manipulated using Adobe Photoshop to produce monochromatic designs where the background had been 'rubbed out'. This method of producing several manifestations of one design on a dress by means of projection and presenting them in a paired comparison method enabled the design process to happen quickly, efficiently and cheaply.

The dresses were presented to the observers mainly on a white background and in some cases a black or grey background. The purpose of this, to establish whether the irradiation effect was apparent when viewing white and black dresses on different backgrounds and whether this affected the choice made by the observer, was the only environmental factor that was considered.

The visual outcome for the practice-based element of this study can be seen in the Digital Sketch Books which are presented alongside this thesis. The processes described above have been summarised and explored through the production of the Digital Sketch Books, printed in a hard copy format to show the clear development of designs and concepts which have formed the main body of design work and investigation throughout the fashion focussed elements of this research.

6.3 Limits of the research

The key research is in the area of perception (of size of printed/patterned clothing on the female form), study set up (using the Caltyre scale and paired comparison methods) and the ability to reach observers (through Bristol Online Surveys). Psychological literature was examined and scientific methods using equipment were explored as a foundation to this research. It was established

that a wholly scientific approach to the subject matter was stifling creativity and was impractical in this researcher's environment. The initial approach was also impractical because of the small number of respondents available and the technical limitations of this researcher's situation. However, the initial limited testing using possible scientific methods gave a solid grounding for the paired comparison method which was adopted for the trialling of designs. Without this scientific beginning a suitable method would have been hard to prove as successful and valid. The purely scientific approach was eliminated but the experiments needed to be carried out to be able to make that decision. For example the interim power Point test described in Chapter 4 section 4.4, and displayed in The Digital Sketch Book The Patterns, was an important step exploring the viability of using a computer based survey which in turn led to the creation of the Bristol Online Surveys. Not only did this provide an appropriate platform for presenting the dress comparisons but was easily distributed via social media and email.

Some of the minor questions that resulted from the literature review and the surveys could not be addressed without certain specialist equipment operated by trained professionals. Neither specialist equipment nor the trained professionals to operate it were available to the researcher within the constraints of this study: Possible further research could encompass the use of equipment such as Brain wave monitoring devices to establish differences in brain patterns depending on images shown. The use of eye recognition equipment to monitor eye movements when observers are choosing left or right and to establish whether or not certain patterns or combinations of monochromatic designs trigger certain responses. Piaget and Bang (1961) discussed the change in optical effect that an illusion had depending on where the observer focussed. The over and underestimation of size described by them could be explored further with eye recognition equipment and could perhaps control to some extent one of the uncontrollable elements in human perception when looking at visual cues.

It was decided that a monochromatic study in line with the optical illusion literature that was reported on was the ideal focus for this research as it was in line with the original illusions which provided the design stimulus. Some initial

work on colour is shown in the Digital Sketchbooks and a possible process for conducting a study including colour could be deducted from the current research.

6.4 Design conclusions

During the process of work carried out, described in Chapter 6, several design conclusions were made, most notably that working in monochrome; black, white and grey gave the best results for the experiments that were carried out. Several of the artists looked at in Chapter 3 used black, white and grey in their exploratory work and in their finished pieces. This decision gave both simple and striking results, which can be seen in the Digital Sketch Books. It was important and vital to give a strong foundation to the effects of a monochromatic palette and the use of established optical illusions to form the basis for designs, which were explored in Chapter 5, worked well and would be the starting point for designs if this research were to be taken further. The linear nature and repeatability of certain ambiguities lends itself well to the design process. The possibilities of changing scale and thickness of line can change the perception and appearance of the designs.

6.5 Design direction

A conceptual design collection was produced in the form of the Digital Sketch Books, as an illustration of the methods used in this study. These form the visual outcome of the thesis and display the design process in a format that is intended to capture the impact of the conceptual designs that were produced throughout the experimental period of the research. The conceptual collection visually displays the design process, which formed part of an iterative process to produce designs, which were discussed in Chapter 5. The Digital Sketch Books are a visual representation of some of the possibilities and design permutations that came through working with the established optical illusions of Hering and Wundt. During the culmination of designs, which appear in the Digital Sketch Books, several graphic and linear designs were explored from simple dots and stripes to more complicated designs that were all produced from initial first hand drawings. These different experiments were what inspired

the designs that were used in surveys 1,2 and 4. The process of designing occurred throughout the research process and results of which are recorded in chronological order to take the tacit research and turn it into explicit knowledge.

6.6 Contribution to knowledge

During the course of this research four major results occurred.

1. A method has been created, using photographs manipulated in Photoshop, which could be a useful tool for fashion designers. It can provide the designer with a quick, efficient and inexpensive way to experiment with monochromatic optical pattern placement. The effect of shadow is an important consideration in this method and care must be taken to eliminate unwanted effects when creating the design. Shading on the sides of a dress can make the female form appear bigger or smaller depending on whether the shading is light or dark. This basic application of monochromatic optical pattern relates directly to the Helmholtz square and the Irradiation effect. When there are light shadows bouncing off the side of a black dress regardless of the monochromatic optical pattern that is on it, it appears to the observer to be bigger than it actually is and in some instances, results from the surveys showed that it was perceived as being bigger than a white dress with darker shading on the sides.

This theory is one which could be explored further in future work and research. This method of projecting patterns is fully described and illustrated in the Digital Sketch Books.

2. It has been established that it is possible to translate 2D illusions into 3D designs to compliment a traditional shift dress shape of clothing. However, placement of the monochromatic optical pattern is important. When the Hering illusion was presented on a dress in three different positions the dress with the centre star monochromatic optical pattern at the top of the dress was always chosen as smaller. This suggests that if monochromatic optical pattern is applied in a concentrated way near the top of a dress it will give the illusion of being smaller.

The diagonal lines changed position on the dress depending on where the star area of the design was placed. This could also have been a factor that changed the perceived size of the dress and therefore is another avenue that could be explored further. Body conscious consumers and designers that are inclined to dress or design to flatter/disguise or divert or draw attention to specific areas of the female form can use this evidence to design or dress to accentuate or disguise areas that they wish to show off or hide.

3. This study confirmed the widely held belief that black makes one look smaller. This research has in fact developed a reliable method to ascertain that this common belief is true and it has been proven in a scientific manner with a large number of observers.

4. It has been exhaustively concluded that a paired comparison method is used when choosing between two or more objects/images presented, and that this is the preferred method for observers when their perceptions are challenged. The uncontrollable element in human perception, which is discussed in Chapter 3.3, was considered and clear directions were given to the observers' before starting any of the paired comparison tests. Although the focus on certain areas of the dresses presented could not be controlled, the limited viewing area of a computer screen served to focus the observers' attention and reduce the effect of external environmental factors.

6.7 Fashion design industry benefits

The design process using projections of monochromatic optical pattern that are photographed and then manipulated in Adobe Photoshop to simulate a monochromatic optical patterned dress could be a useful tool for the fashion industry.

Using established illusions as a starting point for designs with a clear idea of how these will affect the perceived size and shape of a clothed female form through quantitative testing methods as detailed in Chapter 5, is another clear industry benefit.

The Digital Sketch Books could be used as a design source, which could be updated and added to over time. It could also be used as a manual to illustrate a design process. Several permutations of designs could be trialed in the same way as was detailed in Chapter 5.

Results such as concentration of monochromatic optical pattern in certain areas of an outfit to draw the eye or create an illusion of slenderness could be referred to, to back up the industry desire to conceal or accentuate. The use of shading as part of a print at the sides of a garment to give a false impression of a female form could also be employed. The Digital Sketch Books or a version of such a piece of work could serve this purpose. Several fashion retailers (My-Wardrobe.com has a denim bar which aids the purchasing of jeans through various tips and advice regarding size/shape and style dependant on body shape/size) provide an online tool which allows consumers to place garments and accessories on top of one another and on one self. A tool known as augmented reality being developed by Zugara and FaceCake Marketing is a method by which a consumer could theoretically place themselves in the Digital Sketch Book. The beginnings of this tool can be seen in a recent blog article by Grove entitled *Augmented Reality Online Shopping: Not the Right Fit (Yet)* (2011). Although still in its infancy the concept is of definite interest to e retailing. The results of this research could provide a starting point for the development of this and other online tools which could allow consumers to benefit from the theory of monochromatic optical pattern placement and to put it into practice. A very recent development is a changeable mannequin which has over 2,000 different body shapes which enables the customer to see what the clothes will look like before buying (MSNBC, 2011). Probably the closest relation to this research is the interactive mirror which has already been showcased in Bloomingdales in New York and Diesel in Tokyo (Clark, 2009).

The co-designing of garments via a digital platform with fashion retailers is also a possible fashion industry benefit. The ability of a consumer to create a dress that addresses perceived problem areas before the purchasing stage could become the norm. This area of online trying on and outfit planning is growing and new innovations in this area are being reported on frequently in fashion blogs and industry websites as detailed above.

6.8 Possible collaborations

Looking at the work of current fashion designers and their references to optical effects and various techniques that are used to show conceptual based ideas, I see a possibility for collaboration with several fashion designers, artists, architects, video artists and also psychologists. Some of these, and a short description of their potential interest, are:

Hamish Morrow

Morrow has used projections to show potential patterns on white dresses on the catwalk. The use of light and pattern to create a conceptual collection produces various outcomes. Working on an aesthetic with possible theatrical outcomes could be very exciting and he has been known to collaborate on projects working with Nick Thornton-Jones, Warren Du Preez and United Visual Artists on the film 'Fashion in Zero Gravity'.

Beau Lotto

Lottolab studios focus is on "controlled experiments on the perception and behaviour of humans, bumblebees and evolved artificial life systems in laboratory and public realms". Their focus on research with optical illusions could provide a different angle for research into the perception of the clothed body and the intellectual platform that they operate on could open up undiscovered avenues.

Marimekko

Designers at Marimekko have always used bold and optical prints. Perhaps having a scientific basis for collaborative designs could benefit both designer and consumer.

Havard Pedersen

Using dazzle camouflage to inspire and produce work in collaboration where the effects of dazzle could be applied to fashion and textiles.

Irina Shaposhnikova

Shaposhnikova has demonstrated amazing skill at designing and producing geometric clothing based on crystal forms. Bringing together skills where a 2D aesthetic could be realised as a 3D form in a new permutation of optical illusion and clothing presenting an art form

Mary Katrantzou

With “a hyperrealist aesthetic” and architectural designs with a completely flat finish, Katrantzou’s designs could be analysed and evolve with the method of projection and potential perception benefits.

Mr Beam, Daniel Rossa and other video mapping experts

Possible catwalk opportunities where designs could be showcased using skills and techniques where Mr Beam uses video mapping effects to create changing and evolving imagery on a blank background. The concept of having a blank canvas as a starting point whilst changing the design as the models walk.

Matt W. Moore

Moore’s optical illustrations have been applied to many surfaces. A collaboration of Moore’s designs and colour palettes combined with optical illusions applied in a fashion context could make for extremely interesting outcomes.

Nick Thornton-Jones, Warren Du Preez

Having worked with leading fashion designers and musicians these photographers have an eclectic portfolio of images and video. The possibility to create an evolving three dimensional installation of moving image showcasing potential fashion designs in a modern and unusual way.

6.9 Recommendations for future work

Several opportunities for future work could be considered with relation to this research. Due to the constraints and limitations of this study certain aspects of fashion design were not undertaken and these approaches could give weight and add benefits to the existing contribution to knowledge. There is an opportunity to look at the benefit of pattern cutting and in particular drape on the female form and how using different weights of fabric could have an effect on the perceived size of the female form. This approach would also benefit from researching the differences achieved when using different patterned and coloured fabrics of varying pattern scale.

Monochromatic combinations have featured as the main focus of this study and the relationship of black and white and the printed form versus the projected computer manipulated form could be explored in more detail to highlight the

opportunities and differences when using different media. The prominence of the 'little black dress' could also be a consideration when measuring observers perception of the size of the female form and varying styles would add to the factors to be considered. Differing lengths could be looked at as well as different fashion shapes.

Although several initial ideas using colour are included in the Digital Sketch Books, this was beyond the scope of this present study. Testing colour has great potential for future studies and this has been touched upon in the Digital Sketch books. Future work could involve repeating the experiments that have been detailed in Chapter 5 carried out in colour. The theory of colour could benefit from being explored in a scientific manner but in a fashion context. Theories looking at advancing and receding colours and visual effects that occur when using certain colours together in the area of depth perception and size constancy as discussed by Itten (1992) could provide a rich source for further research. This is one area that could benefit greatly from experimentation in a fashion context following some of the same methodology as has been displayed in this thesis.

The inclusion of the live body where printed garments could be constructed and displayed on the live body and the 'real' effects of how different variables behave could be considered in relation to printed pattern. Varying styles of dress could be considered with similar printed patterns and similar styles of dress with differing patterns could also be explored.

There is also the area of consumer culture to be considered where choice and availability of styles, colours and patterns could be observed in the market place.

6.10 References

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PERCEPTION OF BODY SHAPE

School of Textiles and Design

CONSENT FORM

Title of Project: Perception of Body Shape

Name of Researcher: Lynsey Calder

1. I confirm that I have read and understand the Plain Language Statement for the above study and have had the opportunity to ask questions.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

3. I understand that my name will not be used in any written work or any publication arising from the research.

4. I agree / do not agree (delete as applicable) to take part in the above study.

Name of Participant Date Signature

Name of Participant Date Signature

Name of Participant Date Signature

Name of Participant Date Signature

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Name of Participant Date Signature

Name of Participant Date Signature

Name of Participant Date Signature

Name of Participant Date Signature

1 for subject; 1 for researcher

Hi,

Thanks for coming and offering your eyes for my perception experiments.

First I'll give you a brief explanation of what I'm doing for my PhD and then a quick explanation of what I'd like you to do for the experiments.

My PhD is an investigation into the effects of surface pattern (printed) on perceived body shape. I'd like to find out if it's possible to create illusionary prints by manipulating pattern relationships. These prints will then be used for clothing to achieve a particular perceived body shape, whether that is smaller or larger, wider or narrower, taller or shorter etc.

I would like you to put the following shapes I give you in ranking order based on your first impressions. Don't worry too much about whether you're doing the 'right' thing as this is not a test about you! I will specify 'smallest' to 'largest' or 'narrowest' to 'widest' when I hand you the cards.

If you have any questions about the project can you please ask me at the end of the experiments.

Thank you very much.

Lynsey

Please put these in order of Smallest to Biggest

Please put these in order of Shortest to Tallest

Please put these in order or Narrowest to Widest

Please put these in order of Smallest to Biggest

Please put these in order or Narrowest to Widest

Please put these in order of Shortest to Tallest

Thanks for your time

rectangle - length inc

	LENGTH	WIDTH	AREA
R0L	95	70	6650
R1L	**96**	**70**	**6720**
R2L	97	70	6790
R3L	**98**	**70**	**6860**
R4L	99	70	6930
R5L	**100**	**70**	**7000**
R6L	101	70	7070
R7L	**102**	**70**	**7140**
R8L	103	70	7210
R9L	**104**	**70**	**7280**
R10L	105	70	7350

rectangle - width inc

	LENGTH	WIDTH	AREA
R0W	100	66.5	6650
R1W	**100**	**67.2**	**6720**
R2W	100	67.9	6790
R3W	**100**	**68.6**	**6860**
R4W	100	69.3	6930
R5W	**100**	**70**	**7000**
R6W	100	70.7	7070
R7W	**100**	**71.4**	**7140**
R8W	100	72.1	7210
R9W	**100**	**72.8**	**7280**
R10W	100	73.5	7350

rectangle - area inc

	LENGTH	WIDTH	AREA
R0A	95	66.5	6317.5
R1A	96	67.2	6451.2
R2A	97	67.9	6586.3
R3A	**98**	**68.6**	**6722.8**
R4A	**99**	**69.3**	**6860.7**
R5A	**100**	**70**	**7000**
R6A	**101**	**70.7**	**7140.7**
R7A	**102**	**71.4**	**7282.8**
R8A	103	72.1	7426.3
R9A	104	72.8	7571.2
R10A	105	73.5	7717.5

Rectangles of different length – Experiment 1

Twelve observers were given 5 visual samples, (see Figure 1a in Chapter 4) and asked to rank them in order from shortest grey rectangle to longest grey rectangle. Individual responses were recorded where the rectangle identified as 'shortest' was recorded as 1, the next shortest was 2, the mid length rectangle was 3, then 4 and the longest was recorded as 5.

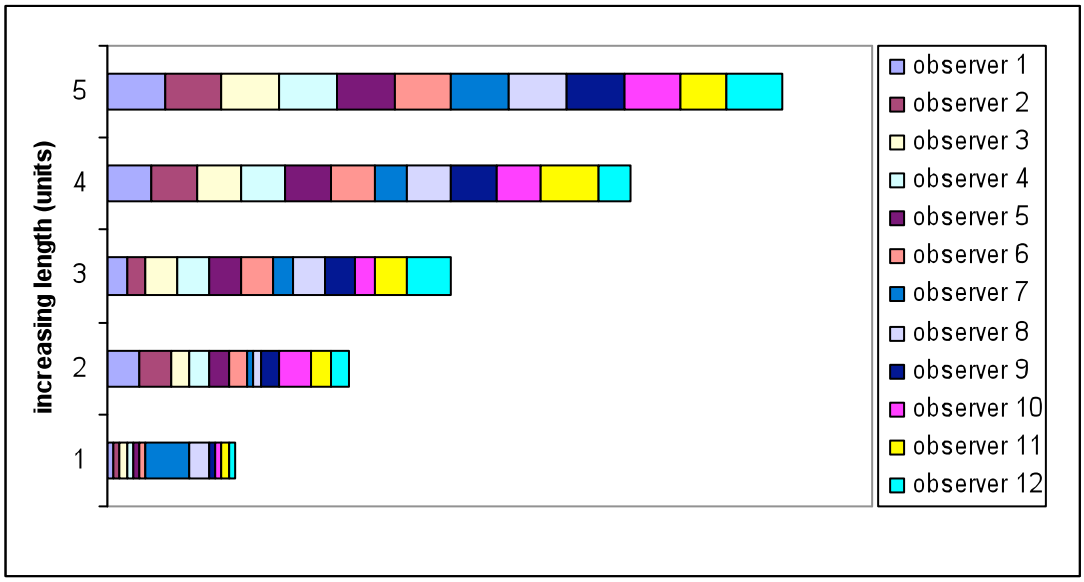


Figure 1 – observers' ranking of rectangles of different length from shortest (1) to longest (5)

Eleven out of the 12 observers ranked the rectangles perfectly (i.e. 1, 2, 3, 4, 5) or with no more than 1 pair of rectangles transposed (e.g. 1, 3, 2, 4, 5). Figure 1 above shows this general trend. Therefore, it was deduced that the mean response of more than 6 observers would consistently be able to perceive a 2% difference in length of approximately 10cm long rectangles. Higher numbers of observers seemed to improve the consistency of the response.

Rectangles of different width – Experiment 2

The observers were given 5 visual samples with increasing width but the same length, (see Figure 1b in Chapter 4), and asked to rank them in order from

narrowest grey rectangle to widest grey rectangle. Individual responses were recorded where the rectangle identified as 'narrowest' was recorded as 1 and the widest was recorded as 5.

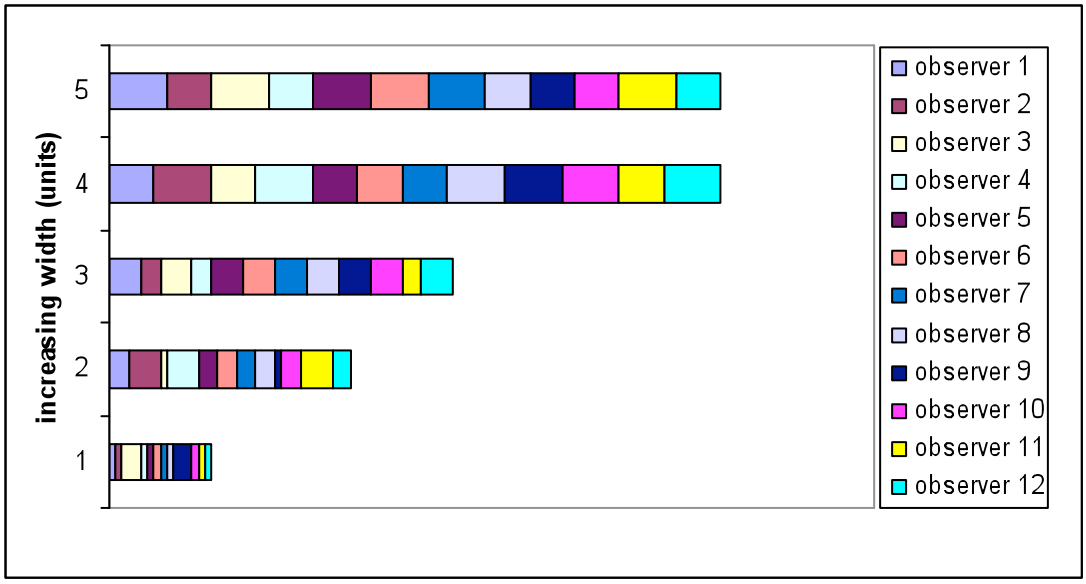


Figure 2 – observers' ranking of samples of different width from narrowest (1) to widest (5)

The results of experiment 2 showed that 9 of the 12 (75%) observers ranked the rectangles from narrowest to widest in a way that significantly correlated with their actual width. Therefore, the mean response of more than 6 observers would consistently be able to perceive a 2% difference in width of approximately 7cm wide rectangles. In this test higher numbers of observers seemed to improve the consistency of the response. Figure 2 showed that overall fewer observers perceived width differences than length differences as in experiment 1. This could be due to the fact that the differences in width were not as big as the differences in length.

Rectangles of different area (width and length) – Experiment 3

Observers were given 5 visual samples, see Figure 1c in Chapter 4, and asked to rank them in order from smallest grey rectangle to biggest grey rectangle. Individual responses were recorded where the rectangle identified as 'smallest' was recorded as 1, and the biggest was recorded as 5.

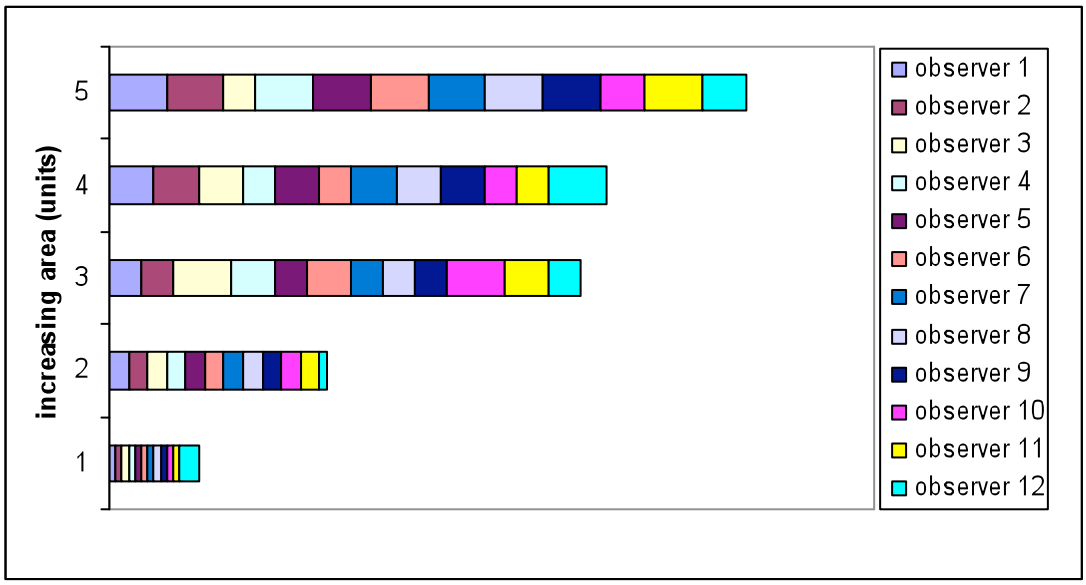


Figure 3 – observers ranked samples of different area from smallest (1) to biggest (5)

The results from experiment 3 showed that 9 out of 12 (75%) observers ranked the rectangles from smallest to biggest correctly. This was considered to be a reasonable result for only 12 observers.

Impact of changing rectangle length on perception of width – Experiment 4

In experiment 4 the width of the rectangle stayed constant however the length changed (as in experiment 1). Observers were asked if the width of the rectangle changed to ascertain whether changing the rectangle's length would have an effect on its perceived width.

Observers were given 5 visual samples of differing length, see Figure 1a in Chapter 4, and asked to rank them in order from narrowest grey rectangle to widest grey rectangle. Individual responses were recorded where the rectangle identified as 'narrowest' was recorded as 1, and the widest was recorded as 5.

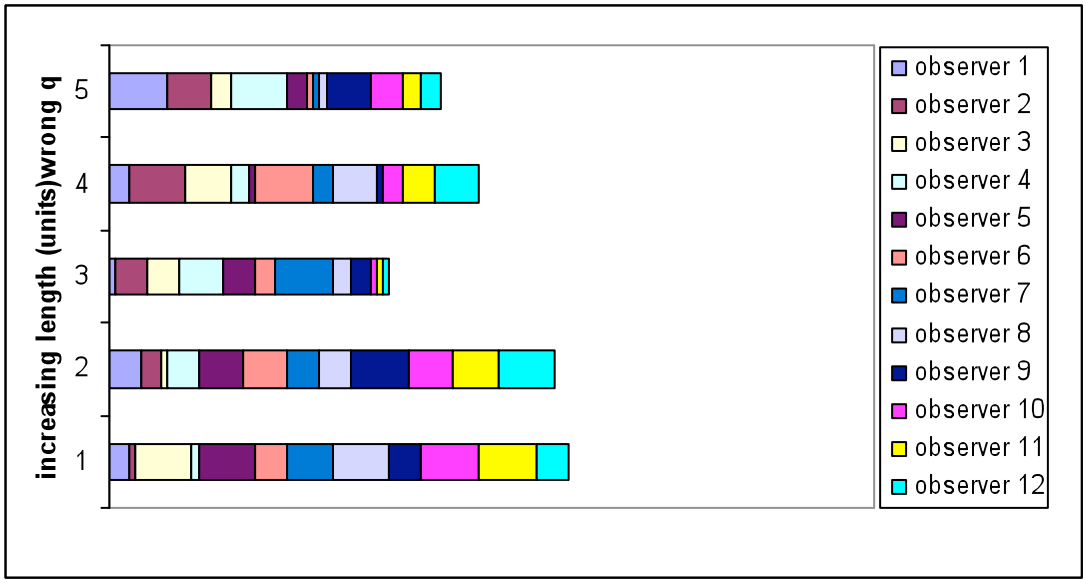


Figure 4 – observers ranked samples of different length from narrowest (1) to widest (5)

The results of experiment 4 showed that 10 out of 12 (83%) observers were unable to perceive a logical difference in rectangle width when width was constant but length changed. Therefore, changing the length of rectangles did not seem to have a significant impact on the way that the width of those rectangles was perceived by individual observers. However, 9 out of 12 observers ranked shorter samples as tending to appear wider. Figure 4 seems to show this insignificant trend, reflecting popular stylist advice, which suggests that taller people automatically look slimmer than shorter people with the same circumferential measurements. However, this illusion of increased width with real reduced length was not as reliably perceived as real differences in perceived dimension.

Note that the 2 logical significant observers' responses were contradictory – 1 observer ranked rectangles as appearing wider when they got longer and 1 observer ranked rectangles as appearing narrower as they got longer.

Impact of changing rectangle width on perception of length – Experiment 5

In experiment 5 the length of the rectangle stayed constant and the width changed as in experiment 2. Observers were asked if the length of the

rectangle changed to ascertain whether changing the rectangles width would have an effect on the perceived length of the rectangle.

Observers were given 5 visual samples of differing width, see Figure 1b in Chapter 4, and asked to rank them in order from shortest grey rectangle to longest grey rectangle. Individual responses were recorded where the rectangle identified as 'shortest' was recorded as 1, and the longest was recorded as 5.

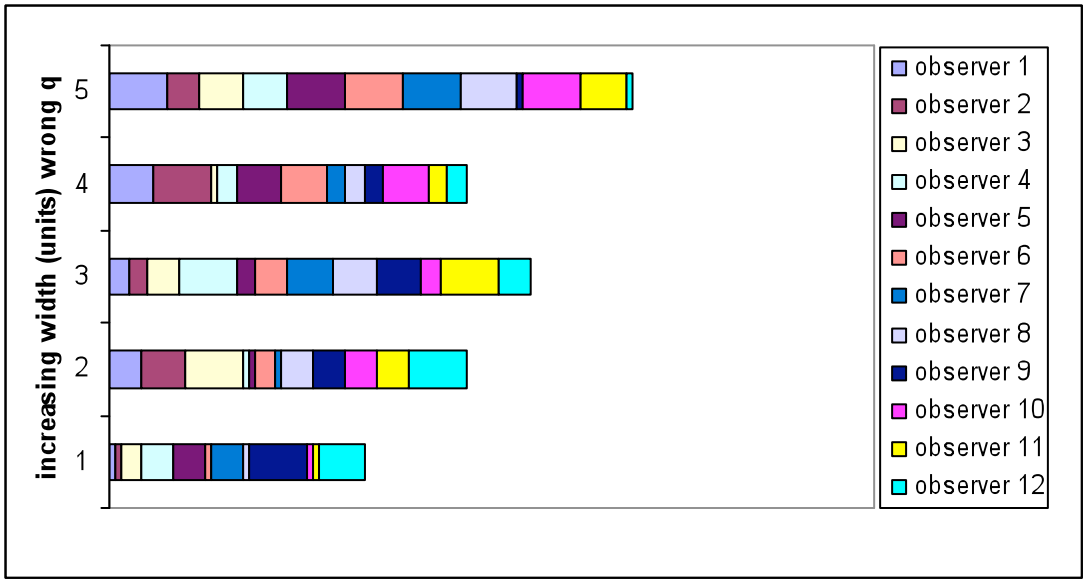


Figure 5 – observers ranked samples of different width from shortest (1) to longest (5)

Three observers ranked rectangles as appearing longer when their width increased (length was actually constant at 10cm). 2 observers ranked rectangles as appearing shorter when their width increased. The remaining 7 observers perceived no significant reliable relationship between increasing rectangle width and perceived length. Figure 5 shows that the average responses of observers also gave variable results. This indicates that no

general trend was found in this experiment and that more observers needed to be used to identify any possible trend.

rectangles of different length

shortest-longest experiment - real difference

observers	LENGTH	WIDTH	AREA	LM	Andr	Steve	Laura	jamie	basel	carol	sherry	hamed	anna	gail	pippa
1	**96**	**70**	**6720**	1	1	1	1	1	1	7	3	1	1	1	1
3	**98**	**70**	**6860**	5	5	3	3	3	3	1	1	3	5	3	3
5	**100**	**70**	**7000**	3	3	5	5	5	5	3	5	5	3	5	7
7	**102**	**70**	**7140**	7	7	7	7	7	7	5	7	7	7	9	5
9	**104**	**70**	**7280**	9	9	9	9	9	9	9	9	9	9	7	9

rectangles of different length

narrowest-widest experiment - wrong question

observers	LENGTH	WIDTH	AREA	LM	Andr	Steve	Laura	jamie	basel	carol	sherry	hamed	anna	gail	pippa
1	**96**	**70**	**6720**	3	1	9	1	9	5	7	9	5	9	9	5
3	**98**	**70**	**6860**	5	3	1	5	7	7	5	5	9	7	7	9
5	**100**	**70**	**7000**	1	5	5	7	5	3	9	3	3	1	1	1
7	**102**	**70**	**7140**	3	9	7	3	1	9	3	7	1	3	5	7
9	**104**	**70**	**7280**	9	7	3	9	3	1	1	1	7	5	3	3

rectangles of different width

shortest-longest experiment - wrong question

	LENGTH	WIDTH	AREA	LM	Andr	Steve	Laura	jamie	basel	carol	sherry	hamed	anna	gail	pippa
R1W	**100**	**67.2**	**6720**	1	1	3	5	5	1	5	1	9	1	1	7
R3W	**100**	**68.6**	**6860**	5	7	9	1	1	3	1	5	5	5	5	9
R5W	**100**	**70**	**7000**	3	3	5	9	3	5	7	7	7	3	9	5
R7W	**100**	**71.4**	**7140**	7	9	1	3	7	7	3	3	3	7	3	3
R9W	**100**	**72.8**	**7280**	9	5	7	7	9	9	9	9	1	9	7	1

rectangles of different width

narrowest-widest experiment - real differnce

	LENGTH	WIDTH	AREA	LM	Andr	Steve	Laura	jamie	basel	carol	sherry	hamed	anna	gail	pippa
R1W	**100**	**67.2**	**6720**	1	1	3	1	1	1	1	1	3	1	1	1
R3W	**100**	**68.6**	**6860**	3	5	1	5	3	3	3	3	1	3	5	3
R5W	**100**	**70**	**7000**	5	3	5	3	5	5	5	5	5	5	3	5
R7W	**100**	**71.4**	**7140**	7	9	7	9	7	7	7	9	9	9	7	9
R9W	**100**	**72.8**	**7280**	9	7	9	7	9	9	9	7	7	7	9	7

rectangles of different areas

smallest-biggest experiment - real difference

	LENGTH	WIDTH	AREA	LM	Andr	Steve	Laura	jamie	basel	carol	sherry	hamed	anna	gail	pippa
R1A	**96**	**67.2**	**6451.2**	1	1	1	1	1	1	1	1	1	1	1	3
R3A	**98**	**68.6**	**6722.8**	3	3	3	3	3	3	3	3	3	3	3	1
R5A	**100**	**70**	**7000**	5	5	9	7	5	7	5	5	5	9	7	5
R7A	**102**	**71.4**	**7282.8**	7	7	7	5	7	5	7	7	7	5	5	9
R9A	**104**	**72.8**	**7571.2**	9	9	5	9	9	9	9	9	9	7	9	7

Appendix E - Ranking results for 4mm, 3mm, 2mm and 1mm differences in area of inner square

Ranking of Black Squares on Grey samples (4mm difference) - R4

	observer					average
sample size	**1**	**2**	**3**	**4**	**5**	**response**
19.2	19.2	19.2	19.2	19.2	19.2	19.2
19.6	19.6	19.6	19.6	19.6	19.6	19.6
20	20	20	20	20	20.4	20.08
20.4	20.4	20.4	20.4	20.4	20	20.32
20.8	20.8	20.8	20.8	20.8	20.8	20.8

Ranking of Black Squares on Grey samples (3mm difference) - R3

	observer					average
sample size	**1**	**2**	**3**	**4**	**5**	**response**
19.4	19.4	19.4	19.7	19.7	19.4	19.52
19.7	19.7	19.7	19.4	19.4	19.7	19.58
20	20	20	20	20	20.3	20.06
20.3	20.3	20.3	20.6	20.2	20.6	20.4
20.6	20.6	20.6	20.3	20.6	20	20.42

Ranking of Black Squares on Grey samples (2mm difference) - R2

	observer					average
sample size	**1**	**2**	**3**	**4**	**5**	**response**
19.6	19.8	19.6	19.6	19.6	19.6	19.64
19.8	19.6	20.2	19.8	20.4	20.2	20.04
20	20	20	20	19.8	19.8	19.92
20.2	20.2	19.8	20.2	20.2	20	20.08
20.4	20.4	20.4	20.4	20	20.4	20.32

Ranking of Black Squares on Grey samples (1mm difference) - R1

	observer					average
sample size	**1**	**2**	**3**	**4**	**5**	**response**
19.8	20	19.8	20	19.9	19.9	19.92
19.9	20.2	19.9	20.1	19.8	20.2	20.04
20	20.1	20	19.8	20	19.8	19.94
20.1	19.8	20.1	20.2	20.1	20.1	20.06
20.2	19.9	20.2	19.9	20.2	20	20.04

Appendix F - Paired Comparison results for 4mm, 3mm, 2mm and 1mm differences in area of inner square

Black Squares on Grey samples (4mm difference) - paired comparison tally

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.2	0	0	0	0	0	0
19.6	1	1	1	1	1	1
20	2	2	2	2	2	2
20.4	3	3	3	4	3	3.2
20.8	4	4	4	3	4	3.8

Black Squares on Grey samples (3mm difference) - paired comparison tally

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.4	0	0	0	1	0	0.2
19.7	1	1	1	1	1	1
20	3	2	2	1	3	2.2
20.3	2	4	3	4	2	3
20.6	4	3	4	3	4	3.6

Black Squares on Grey samples (2mm difference) - paired comparison tally

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.6	0	1	0	0	0	0.2
19.8	1	0	1	2	2	1.2
20	2	2	2	1	1	1.6
20.2	3	4	3	3	3	3.2
20.4	4	3	4	4	4	3.8

Black Squares on Grey samples (1mm difference) - paired comparison tally

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.8	1	1	0	1	0	0.6
19.9	0	1	1	2	1	1
20	1	3	3	3	2	2.4
20.1	3	2	2	2	4	2.6
20.2	4	3	4	2	3	3.2

Appendix G - Rating with the Caltyre scale results for 4mm, 3mm, 2mm and 1mm differences in area of inner square

Black Squares on Grey samples (4mm difference) matched to 4mm Caltyre Scale

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.2	19.2	19.6	19.2	18.8	19.2	19.2
19.6	19.6	19.6	19.6	19.2	20	19.6
20	20	20	20	20	20.4	20.08
20.4	20.8	20.4	20.4	20.4	20.8	20.56
20.8	20.4	20.4	20.8	19.6	21.2	20.48

Black Squares on Grey samples (3mm difference) matched to 3mm Caltyre Scale

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.4	19.4	19.1	19.4	19.4	19.4	19.34
19.7	19.7	19.4	19.7	19.7	20	19.7
20	20.3	19.7	20	20.3	20.3	20.12
20.3	20.3	19.7	20.3	20.3	20.3	20.18
20.6	20.6	20.9	20.6	20.6	20.6	20.66

Black Squares on Grey samples (2mm difference) matched to 2mm Caltyre Scale

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.6	19.8	19.6	19.6	20.2	20	19.84
19.8	19.6	19.8	20	20.6	20	20
20	20.2	19.6	20.4	20.4	20.4	20.2
20.2	20	20.4	20.2	20.4	20.4	20.28
20.4	20.2	20.1	20.4	20.6	20.4	20.34

Black Squares on Grey samples (1mm difference) matched to 1mm Caltyre Scale

	observer					
sample size	**1**	**2**	**3**	**4**	**5**	**average response**
19.8	19.8	19.8	19.8	19.9	19.9	19.84
19.9	19.9	20.1	20	20.1	20	20.02
20	20.3	19.8	20.1	19.9	20.2	20.06
20.1	20	19.9	20.1	20.2	20.2	20.08
20.2	20.3	19.8	20	20	20.2	20.06

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (1mm difference)

size 20 inner square was bigger (enter 1), smaller (enter -1), same as (enter 0) stated size of caltyre scale

observer	19.8	19.9	20	20.1	20.2
1	1	1	1	1	-1
2	1	1	0	0	0
3	1	1	-1	-1	0
4	-1	1	1	1	0
5	1	0	0	-1	0
6	0	0	0	0	1
7	1	1	-1	0	-1
8	1	0	1	0	-1
9	1	0	1	1	0
10	1	1	1	-1	0
mean	0.7	0.6	0.3	0	-0.2
truth	1	1	0	-1	-1
% correct	80	60	30	30	30
mm diff	2	1	0	1	2

size 19.9 inner square was bigger (enter 1), smaller (enter -1), same as (enter 0) stated size of caltyre scale

observer	19.8	19.9	20	20.1	20.2
1	-1	1	0	-1	-1
2	0	1	0	1	-1
3	1	0	-1	-1	-1
4	1	0	-1	-1	-1
5	-1	-1	0	-1	-1
6	0	0	0	1	0
7	0	1	-1	-1	-1
8	-1	-1	1	-1	-1
9	1	1	-1	-1	-1
10	-1	1	-1	0	-1
mean	-0.1	0.3	-0.4	-0.5	-0.9
truth	1	0	-1	-1	-1
%correct	30	30	50	70	90
mm diff	1	0	1	2	3

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (1mm difference)

size 20 inner square was bigger (enter 1) or smaller (enter -1) than stated size of caltyre scale

observer	19.8	19.9	20	20.1	20.2
1	1	1	-1	1	-1
2	1	1	1	-1	1
3	-1	1	1	-1	1
4	1	1	-1	-1	-1
5	1	1	-1	1	1
6	1	-1	1	1	1
7	1	1	1	1	-1
8	1	1	1	1	-1
9	-1	1	1	-1	-1
10	1	-1	1	-1	-1
mean	0.6	0.6	0.4	0	-0.2
truth	1	1	0	-1	-1
% correct	80	80	0	50	60
mm diff	2	1	0	1	2

size 19.9 inner square was bigger (enter 1) or smaller (enter -1) than stated size of caltyre scale

observer	19.8	19.9	20	20.1	20.2
1	1	1	-1	-1	-1
2	1	1	-1	-1	-1
3	1	-1	-1	-1	-1
4	1	1	1	-1	-1
5	1	-1	-1	-1	-1
6	1	-1	1	1	1
7	-1	1	-1	-1	1
8	-1	1	1	-1	-1
9	1	1	1	-1	-1
10	-1	1	-1	-1	-1
mean	0.4	0.4	-0.2	-0.8	-0.6
truth	1	0	-1	-1	-1
% correct	70	0	60	90	80
mm diff	1	0	1	2	3

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (2mm difference)

size 20 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0) stated size of caltyre scale

observer		19.6	19.8	20	20.2	20.4
	1	2	2	2	0	-2
	2	2	0	0	-2	-2
	3	2	0	0	-2	-2
	4	2	0	-2	-2	-2
	5	2	2	2	0	-2
	6	2	0	-2	-2	0
	7	2	-2	2	-2	-2
	8	-2	2	2	-2	-2
	9	0	2	2	0	-2
	10	2	2	0	2	-2
mean		1.4	0.8	0.6	-1	-1.8
truth		2	2	0	-2	-2
% correct		80	50	30	60	90
mm diff		4	2	0	2	4

size 20.4 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0) stated size of caltyre scale

observer		19.6	19.8	20	20.2	20.4
	1	2	2	2	2	-2
	2	2	2	2	0	2
	3	2	2	2	2	0
	4	2	2	2	0	0
	5	2	2	2	2	2
	6	0	2	2	2	0
	7	2	2	2	2	2
	8	0	2	0	2	2
	9	2	2	2	2	0
	10	2	2	2	2	0
mean		1.6	2	1.8	1.6	0.6
truth		2	2	2	2	0
% correct		80	100	90	80	50
mm diff		8	6	4	2	0

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (2mm difference)

size 20 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0) stated size of caltyre scale

observer		19.6	19.8	20	20.2	20.4
	1	2	2	-2	2	-2
	2	2	-2	2	2	-2
	3	2	2	2	-2	-2
	4	-2	2	2	-2	2
	5	2	2	-2	2	-2
	6	2	2	-2	2	-2
	7	2	-2	-2	2	-2
	8	2	2	2	-2	-2
	9	2	2	2	-2	-2
	10	2	2	2	-2	-2
mean		1.6	1.2	0.4	0	-1.6
truth		2	2	0	-2	-2
% correct		90	80	0	50	90
mm diff		4	2	0	2	4

size 20.4 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0) stated size of caltyre scale

observer		19.6	19.8	20	20.2	20.4
	1	2	2	2	2	-2
	2	2	2	2	2	2
	3	2	2	2	2	-2
	4	-2	-2	2	-2	2
	5	2	2	-2	2	-2
	6	2	2	2	2	-2
	7	2	2	2	2	2
	8	2	2	2	2	-2
	9	2	2	2	2	2
	10	2	2	2	2	2
mean		1.6	1.6	1.6	1.6	0
truth		2	2	2	2	0
% correct		90	90	90	90	0
mm diff		8	6	4	2	0

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (3mm difference)

size 20 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0) stated size of caltyre scale

observer		19.4	19.7	20	20.3	20.6
	1	3	3	3	-3	-3
	2	3	0	0	-3	-3
	3	3	3	0	3	-3
	4	3	3	-3	0	0
	5	3	-3	0	-3	-3
	6	3	0	0	-3	0
	7	3	3	0	-3	-3
	8	3	-3	0	-3	-3
	9	3	0	3	-3	-3
	10	3	-3	3	0	-3
mean		3	0.3	0.6	-1.8	-2.4
truth		3	3	0	-3	-3
% correct		100	40	60	70	80
mm diff		6	3	0	3	6

size 20.3 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0) stated size of caltyre scale

observer		19.4	19.7	20	20.3	20.6
	1	3	3	3	-3	-3
	2	3	3	3	0	-3
	3	3	3	3	0	-3
	4	3	3	0	-3	-3
	5	3	-3	3	-3	-3
	6	3	3	0	0	-3
	7	3	-3	0	0	-3
	8	3	3	3	3	-3
	9	3	3	0	0	0
	10	3	3	-3	0	-3
mean		3	1.8	1.2	-0.6	-2.7
truth		3	3	3	0	-3
% correct		100	80	50	60	90
mm diff		9	6	3	0	3

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (3mm difference)

size 20 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0) stated size of caltyre scale

observer	19.4	19.7	20	20.3	20.6
1	3	3	3	-3	-3
2	3	3	-3	-3	-3
3	3	3	-3	-3	-3
4	3	-3	-3	-3	-3
5	3	3	3	-3	-3
6	3	3	-3	-3	-3
7	3	3	-3	-3	-3
8	3	3	3	-3	-3
9	3	3	3	-3	-3
10	3	3	3	-3	-3
mean	3	2.4	0	-3	-3
truth	3	3	0	-3	-3
% correct	100	90	0	100	100
mm diff	6	3	0	3	6

size 20.3 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0) stated size of caltyre scale

observer	19.4	19.7	20	20.3	20.6
1	3	3	3	3	-3
2	3	3	3	3	3
3	3	3	3	-3	-3
4	3	3	3	3	-3
5	3	3	3	-3	-3
6	3	3	3	-3	-3
7	3	3	3	-3	-3
8	3	3	3	3	-3
9	3	3	3	3	-3
10	3	3	3	3	-3
mean	3	3	3	0.6	-2.4
truth	3	3	3	0	-3
% correct	100	100	100	0	90
mm diff	9	6	3	0	3

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (4mm difference)

size 20 inner square was bigger (enter 4), smaller (enter -4), same as (enter 0) stated size of caltyre scale

observer		19.2	19.6	20	20.4	20.8
	1	4	4	0	-4	-4
	2	4	4	0	-4	-4
	3	4	4	0	-4	-4
	4	4	0	4	-4	-4
	5	4	4	4	0	-4
	6	4	0	0	-4	-4
	7	4	4	0	-4	-4
	8	4	4	0	-4	-4
	9	4	0	0	0	-4
	10	4	4	0	-4	-4
mean		4	2.8	0.8	-3.2	-4
truth		4	4	0	-4	-4
% correct		100	70	80	80	100
mm diff		8	4	0	4	8

size 19.2 inner square was bigger (enter 4), smaller (enter -4), same as (enter 0) stated size of caltyre scale

observer		19.2	19.6	20	20.4	20.8
	1	0	-4	-4	-4	-4
	2	0	-4	-4	-4	-4
	3	0	-4	-4	-4	-4
	4	4	4	-4	4	-4
	5	4	4	-4	-4	-4
	6	0	-4	-4	-4	-4
	7	0	-4	-4	-4	-4
	8	0	-4	-4	-4	-4
	9	0	-4	-4	-4	-4
	10	0	-4	-4	-4	-4
mean		0.8	-2.4	-4	-3.2	-4
truth		0	-4	-4	-4	-4
% correct		80	80	100	90	100
mm diff		0	4	8	12	16

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (4mm difference)

size 20 inner square was bigger (enter 4) or smaller (enter -4) than stated size of caltyre scale

observer		19.2	19.6	20	20.4	20.8
observer 1		4	-4	-4	-4	-4
	2	4	4	-4	-4	-4
	3	4	4	-4	-4	-4
	4	4	4	4	-4	-4
	5	4	4	-4	-4	-4
	6	4	4	4	-4	-4
	7	4	4	-4	-4	-4
	8	4	4	-4	-4	-4
	9	4	4	4	-4	-4
	10	4	4	4	-4	-4
mean		4	3.2	-0.8	-4	-4
truth		4	4	0	-4	-4
% correct		100	90	0	100	100
mm diff		8	4	0	4	8

size 19.2 inner square was bigger (enter 4) or smaller (enter -4) than stated size of caltyre scale

observer		19.2	19.6	20	20.4	20.8
	1	-4	-4	-4	-4	-4
	2	4	-4	-4	-4	-4
	3	4	-4	-4	-4	-4
	4	-4	4	-4	-4	-4
	5	-4	4	-4	-4	-4
	6	4	-4	-4	-4	-4
	7	-4	-4	-4	-4	-4
	8	-4	-4	-4	-4	-4
	9	4	-4	-4	-4	-4
	10	4	-4	-4	-4	-4
mean		0	-2.4	-4	-4	-4
truth		0	-4	-4	-4	-4
% correct		0	80	100	100	100
mm diff		0	4	8	12	16

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (4mm difference)

size 20 inner square was bigger (enter 4), smaller (enter -4), same as (enter 0) stated size of caltyre scale

observer		19.2	19.6	20	20.4	20.8
	1	4	4	0	-4	-4
	2	4	4	0	-4	-4
	3	4	4	0	-4	-4
	4	4	0	4	-4	-4
	5	4	4	4	0	-4
	6	4	0	0	-4	-4
	7	4	4	0	-4	-4
	8	4	4	0	-4	-4
	9	4	0	0	0	-4
	10	4	4	0	-4	-4
mean		4	2.8	0.8	-3.2	-4
truth		4	4	0	-4	-4
% correct		100	70	80	80	100
mm diff		8	4	0	4	8

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size
size 19.2 inner square was bigger (enter 4), smaller (enter -4), same
as (enter 0) stated size of caltyre scale

observer		19.2	19.6	20	20.4	20.8
	1	0	-4	-4	-4	-4
	2	0	-4	-4	-4	-4
	3	0	-4	-4	-4	-4
	4	4	4	-4	4	-4
	5	4	4	-4	-4	-4
	6	0	-4	-4	-4	-4
	7	0	-4	-4	-4	-4
	8	0	-4	-4	-4	-4
	9	0	-4	-4	-4	-4
	10	0	-4	-4	-4	-4
mean		0.8	-2.4	-4	-3.2	-4
truth		0	-4	-4	-4	-4
% correct		80	80	100	90	100
mm diff		0	4	8	12	16

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (4mm difference)

size 20 inner square was bigger (enter 4) or smaller (enter -4) than stated size of caltyre scale

observer		19.2	19.6	20	20.4	20.8
observer 1		4	-4	-4	-4	-4
	2	4	4	-4	-4	-4
	3	4	4	-4	-4	-4
	4	4	4	4	-4	-4
	5	4	4	-4	-4	-4
	6	4	4	4	-4	-4
	7	4	4	-4	-4	-4
	8	4	4	-4	-4	-4
	9	4	4	4	-4	-4
	10	4	4	4	-4	-4
mean		4	3.2	-0.8	-4	-4
truth		4	4	0	-4	-4
% correct		100	90	0	100	100
mm diff		8	4	0	4	8

Caltyre Scale method 3

question = please tell me which square is bigger
size 19.2 inner square was bigger (enter 4) or smaller (enter -4) than stated
size of caltyre scale

observer	19.2	19.6	20	20.4	20.8
1	-4	-4	-4	-4	-4
2	4	-4	-4	-4	-4
3	4	-4	-4	-4	-4
4	-4	4	-4	-4	-4
5	-4	4	-4	-4	-4
6	4	-4	-4	-4	-4
7	-4	-4	-4	-4	-4
8	-4	-4	-4	-4	-4
9	4	-4	-4	-4	-4
10	4	-4	-4	-4	-4
mean	0	-2.4	-4	-4	-4
truth	0	-4	-4	-4	-4
% correct	0	80	100	100	100
mm diff	0	4	8	12	16

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (3mm difference)

size 20 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0) stated size of caltyre scale

observer		19.4	19.7	20	20.3	20.6
	1	3	3	3	-3	-3
	2	3	0	0	-3	-3
	3	3	3	0	3	-3
	4	3	3	-3	0	0
	5	3	-3	0	-3	-3
	6	3	0	0	-3	0
	7	3	3	0	-3	-3
	8	3	-3	0	-3	-3
	9	3	0	3	-3	-3
	10	3	-3	3	0	-3
mean		3	0.3	0.6	-1.8	-2.4
truth		3	3	0	-3	-3
% correct		100	40	60	70	80
mm diff		6	3	0	3	6

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (3mm difference)

size 20.3 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0) stated size of caltyre scale

observer		19.4	19.7	20	20.3	20.6
	1	3	3	3	-3	-3
	2	3	3	3	0	-3
	3	3	3	3	0	-3
	4	3	3	0	-3	-3
	5	3	-3	3	-3	-3
	6	3	3	0	0	-3
	7	3	-3	0	0	-3
	8	3	3	3	3	-3
	9	3	3	0	0	0
	10	3	3	-3	0	-3
mean		3	1.8	1.2	-0.6	-2.7
truth		3	3	3	0	-3
% correct		100	80	50	60	90
mm diff		9	6	3	0	3

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (3mm difference)

size 20 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0)
stated size of caltyre scale

observer	19.4	19.7	20	20.3	20.6
1	3	3	3	-3	-3
2	3	3	-3	-3	-3
3	3	3	-3	-3	-3
4	3	-3	-3	-3	-3
5	3	3	3	-3	-3
6	3	3	-3	-3	-3
7	3	3	-3	-3	-3
8	3	3	3	-3	-3
9	3	3	3	-3	-3
10	3	3	3	-3	-3
mean	3	2.4	0	-3	-3
truth	3	3	0	-3	-3
% correct	100	90	0	100	100
mm diff	6	3	0	3	6

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (3mm difference)

size 20.3 inner square was bigger (enter 3), smaller (enter -3), same as (enter 0) stated size of caltyre scale

observer	19.4	19.7	20	20.3	20.6
1	3	3	3	3	-3
2	3	3	3	3	3
3	3	3	3	-3	-3
4	3	3	3	3	-3
5	3	3	3	-3	-3
6	3	3	3	-3	-3
7	3	3	3	-3	-3
8	3	3	3	3	-3
9	3	3	3	3	-3
10	3	3	3	3	-3
mean	3	3	3	0.6	-2.4
truth	3	3	3	0	-3
% correct	100	100	100	0	90
mm diff	9	6	3	0	3

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (2mm difference)

size 20 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0) stated size of caltyre scale

observer	19.6	19.8	20	20.2	20.4
1	2	2	2	0	-2
2	2	0	0	-2	-2
3	2	0	0	-2	-2
4	2	0	-2	-2	-2
5	2	2	2	0	-2
6	2	0	-2	-2	0
7	2	-2	2	-2	-2
8	-2	2	2	-2	-2
9	0	2	2	0	-2
10	2	2	0	2	-2
mean	1.4	0.8	0.6	-1	-1.8
truth	2	2	0	-2	-2
% correct	80	50	30	60	90
mm diff	4	2	0	2	4

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (2mm difference)

size 20.4 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0) stated size of caltyre scale

observer		19.6	19.8	20	20.2	20.4
	1	2	2	2	2	-2
	2	2	2	2	0	2
	3	2	2	2	2	0
	4	2	2	2	0	0
	5	2	2	2	2	2
	6	0	2	2	2	0
	7	2	2	2	2	2
	8	0	2	0	2	2
	9	2	2	2	2	0
	10	2	2	2	2	0
mean		1.6	2	1.8	1.6	0.6
truth		2	2	2	2	0
% correct		80	100	90	80	50
mm diff		8	6	4	2	0

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (2mm difference)

size 20 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0)
stated size of caltyre scale

observer		19.6	19.8	20	20.2	20.4
	1	2	2	-2	2	-2
	2	2	-2	2	2	-2
	3	2	2	2	-2	-2
	4	-2	2	2	-2	2
	5	2	2	-2	2	-2
	6	2	2	-2	2	-2
	7	2	-2	-2	2	-2
	8	2	2	2	-2	-2
	9	2	2	2	-2	-2
	10	2	2	2	-2	-2
mean		1.6	1.2	0.4	0	-1.6
truth		2	2	0	-2	-2
% correct		90	80	0	50	90
mm diff		4	2	0	2	4

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (2mm difference)

size 20.4 inner square was bigger (enter 2), smaller (enter -2), same as (enter 0) stated size of caltyre scale

observer		19.6	19.8	20	20.2	20.4
	1	2	2	2	2	-2
	2	2	2	2	2	2
	3	2	2	2	2	-2
	4	-2	-2	2	-2	2
	5	2	2	-2	2	-2
	6	2	2	2	2	-2
	7	2	2	2	2	2
	8	2	2	2	2	-2
	9	2	2	2	2	2
	10	2	2	2	2	2
mean		1.6	1.6	1.6	1.6	0
truth		2	2	2	2	0
% correct		90	90	90	90	0
mm diff		8	6	4	2	0

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (1mm difference)

size 20 inner square was bigger (enter 1), smaller (enter -1), same as (enter 0) stated size of caltyre scale

observer	19.8	19.9	20	20.1	20.2
1	1	1	1	1	-1
2	1	1	0	0	0
3	1	1	-1	-1	0
4	-1	1	1	1	0
5	1	0	0	-1	0
6	0	0	0	0	1
7	1	1	-1	0	-1
8	1	0	1	0	-1
9	1	0	1	1	0
10	1	1	1	-1	0
mean	0.7	0.6	0.3	0	-0.2
truth	1	1	0	-1	-1
% correct	80	60	30	30	30
mm diff	2	1	0	1	2

Caltyre Scale method 2

question = please tell me which square is bigger or if they are the same size

Black Squares on Grey samples (1mm difference)

size 19.9 inner square was bigger (enter 1), smaller (enter -1), same as (enter 0) stated size of caltyre scale

observer		19.8	19.9	20	20.1	20.2
	1	-1	1	0	-1	-1
	2	0	1	0	1	-1
	3	1	0	-1	-1	-1
	4	1	0	-1	-1	-1
	5	-1	-1	0	-1	-1
	6	0	0	0	1	0
	7	0	1	-1	-1	-1
	8	-1	-1	1	-1	-1
	9	1	1	-1	-1	-1
	10	-1	1	-1	0	-1
mean		-0.1	0.3	-0.4	-0.5	-0.9
truth		1	0	-1	-1	-1
%correct		30	30	50	70	90
mm diff		1	0	1	2	3

Caltyre Scale method 3

question = please tell me which square is bigger

Black Squares on Grey samples (1mm difference)

size 20 inner square was bigger (enter 1) or smaller (enter -1) than stated size of caltyre scale

observer		19.8	19.9	20	20.1	20.2
	1	1	1	-1	1	-1
	2	1	1	1	-1	1
	3	-1	1	1	-1	1
	4	1	1	-1	-1	-1
	5	1	1	-1	1	1
	6	1	-1	1	1	1
	7	1	1	1	1	-1
	8	1	1	1	1	-1
	9	-1	1	1	-1	-1
	10	1	-1	1	-1	-1
mean		0.6	0.6	0.4	0	-0.2
truth		1	1	0	-1	-1
% correct		80	80	0	50	60
mm diff		2	1	0	1	2

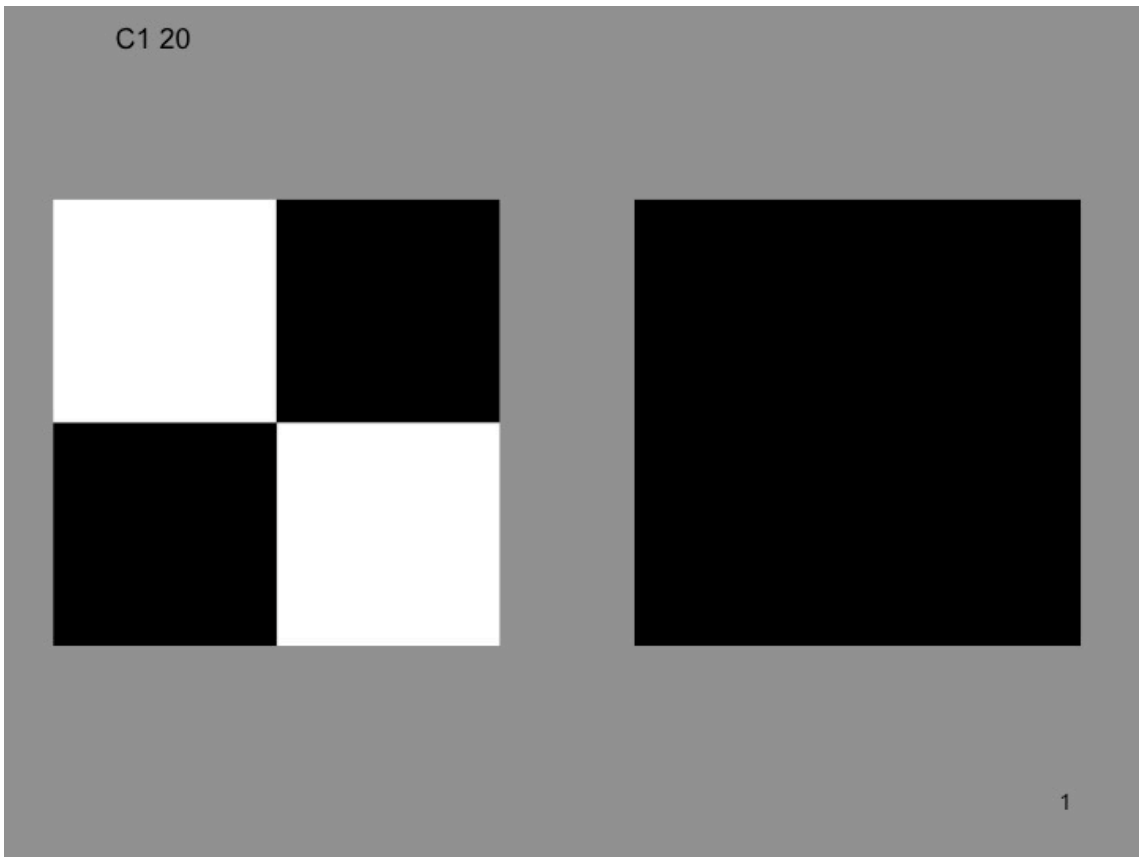
Caltyre Scale method 3

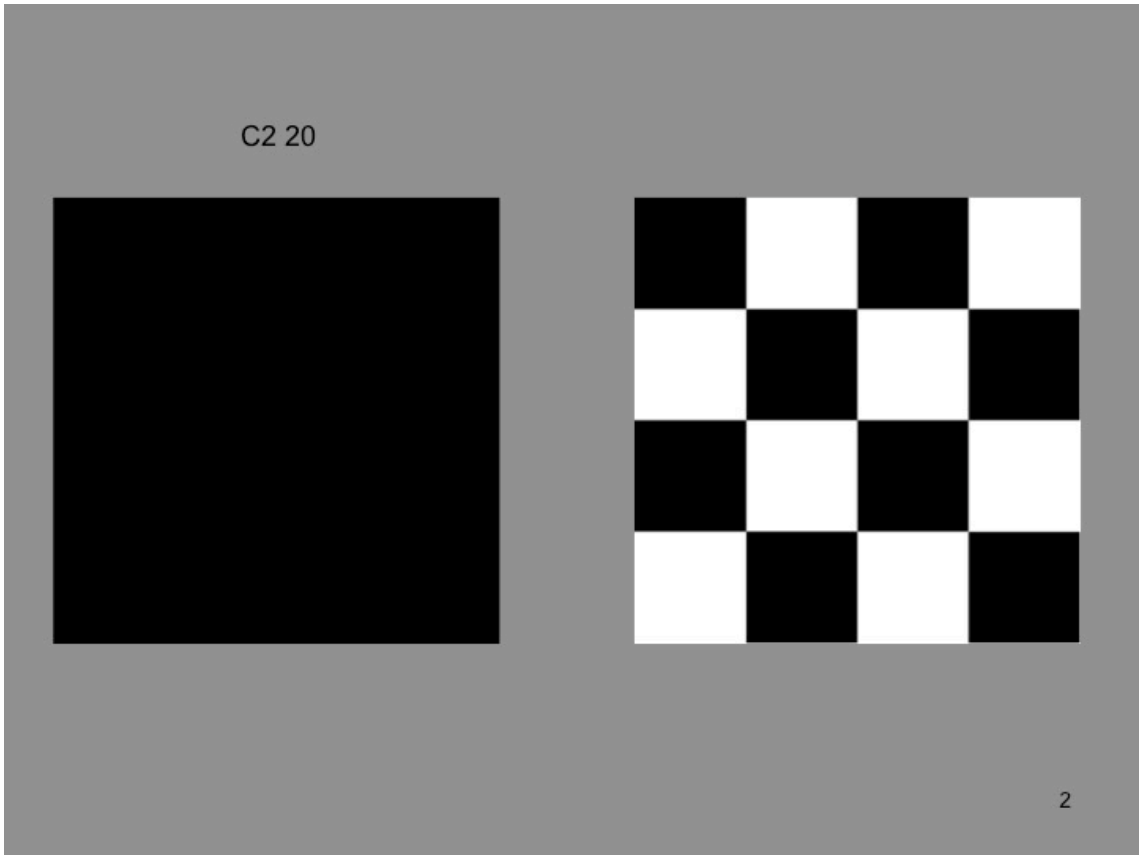
question = please tell me which square is bigger

Black Squares on Grey samples (1mm difference)

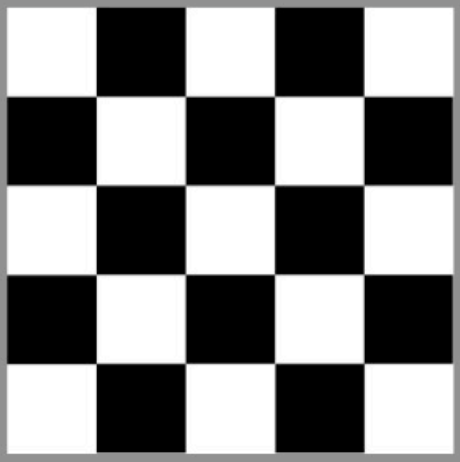
size 19.9 inner square was bigger (enter 1) or smaller (enter -1) than stated size of caltyre scale

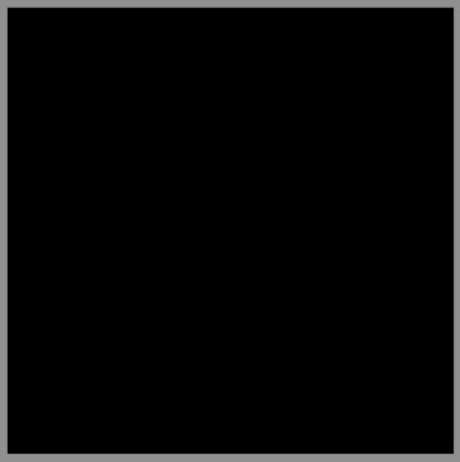
observer		19.8	19.9	20	20.1	20.2
	1	1	1	-1	-1	-1
	2	1	1	-1	-1	-1
	3	1	-1	-1	-1	-1
	4	1	1	1	-1	-1
	5	1	-1	-1	-1	-1
	6	1	-1	1	1	1
	7	-1	1	-1	-1	1
	8	-1	1	1	-1	-1
	9	1	1	1	-1	-1
	10	-1	1	-1	-1	-1
mean		0.4	0.4	-0.2	-0.8	-0.6
truth		1	0	-1	-1	-1
% correct		70	0	60	90	80
mm diff		1	0	1	2	3


C1 20
1


C2 20
2

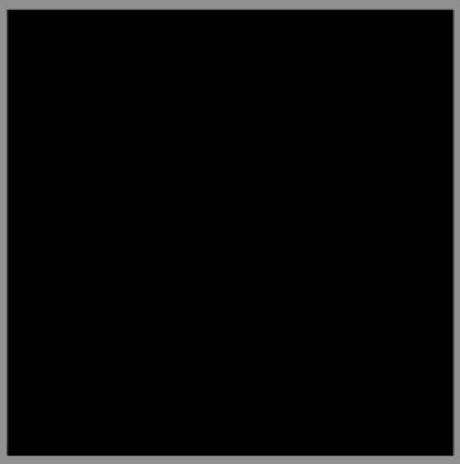
C3 20

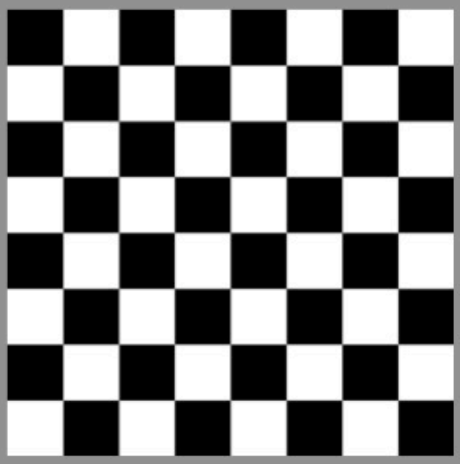




3

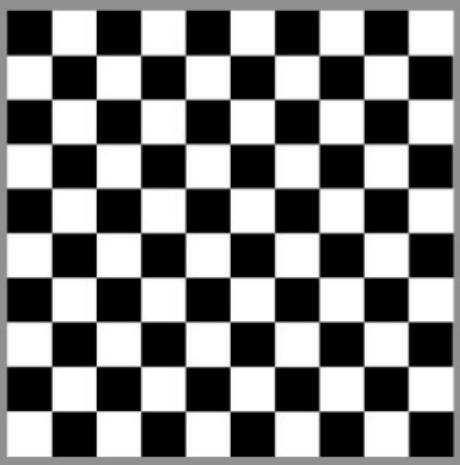
C4 20

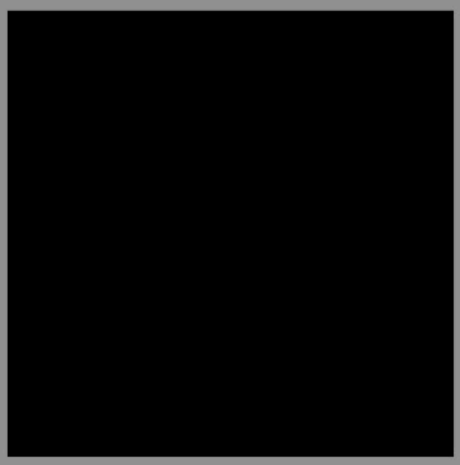




4

C5 20





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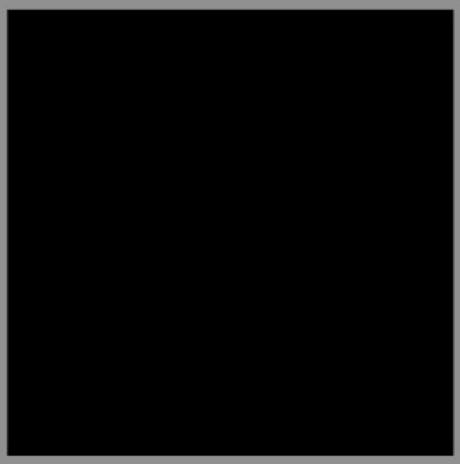
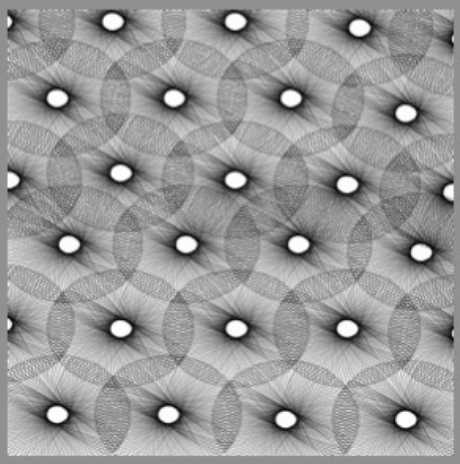
S2 20





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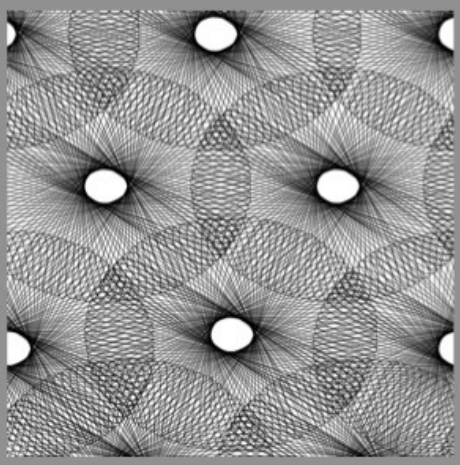
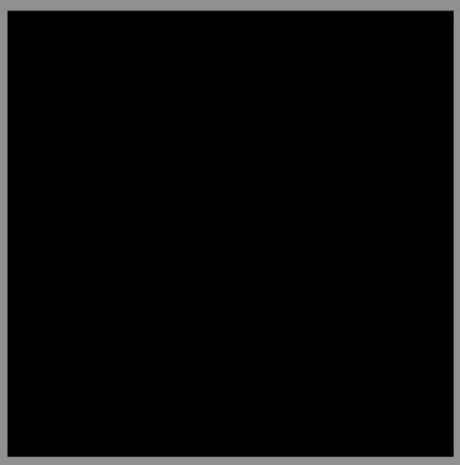
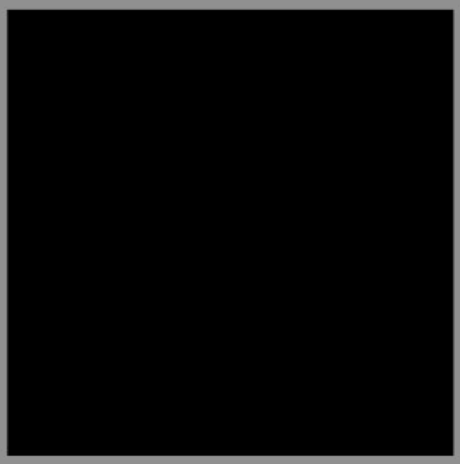
S3 20

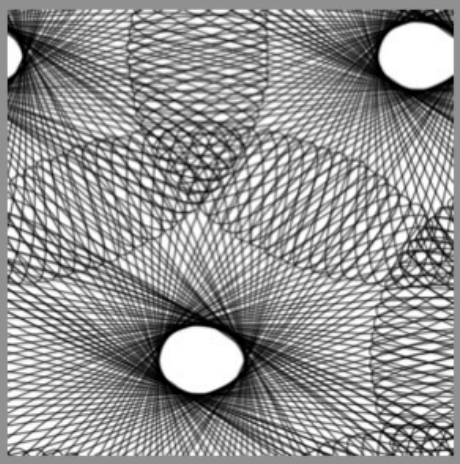




7

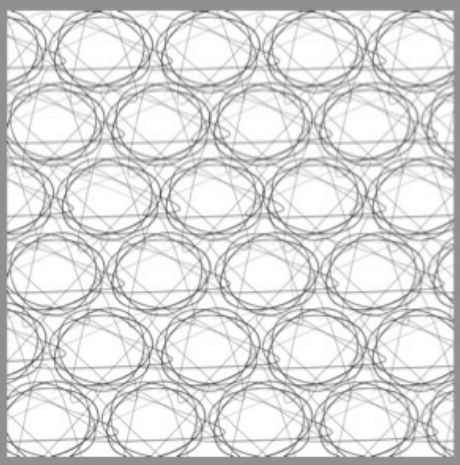
S4 20

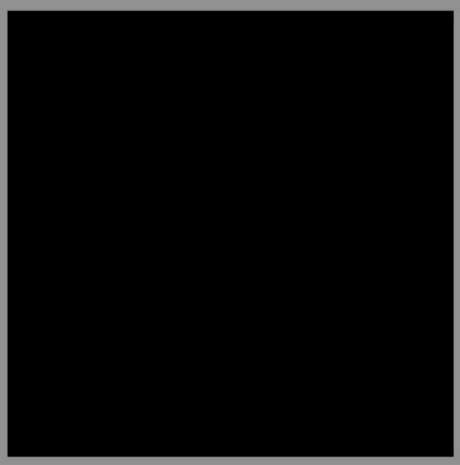




8

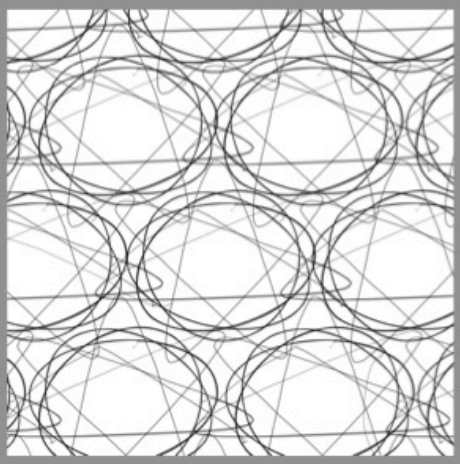
S5 20

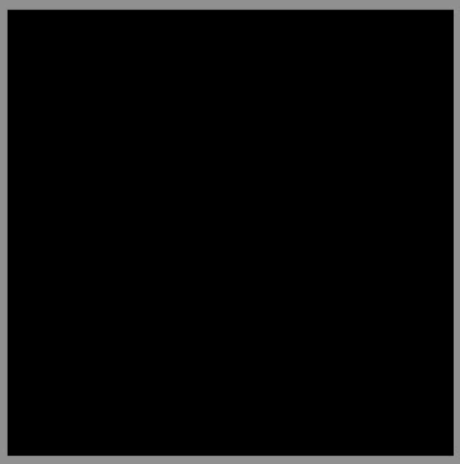




9

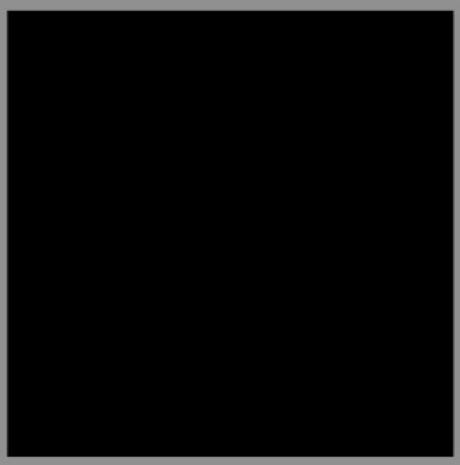
S6 20





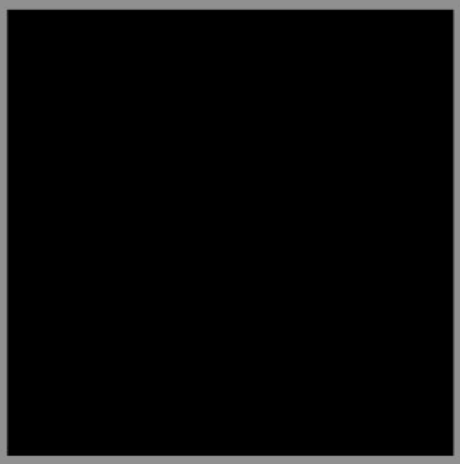
10

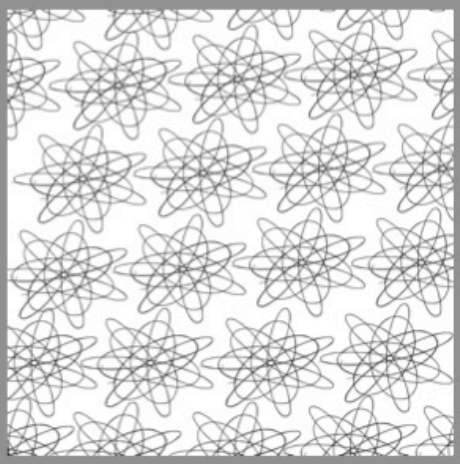
S7 20



11

S8 20





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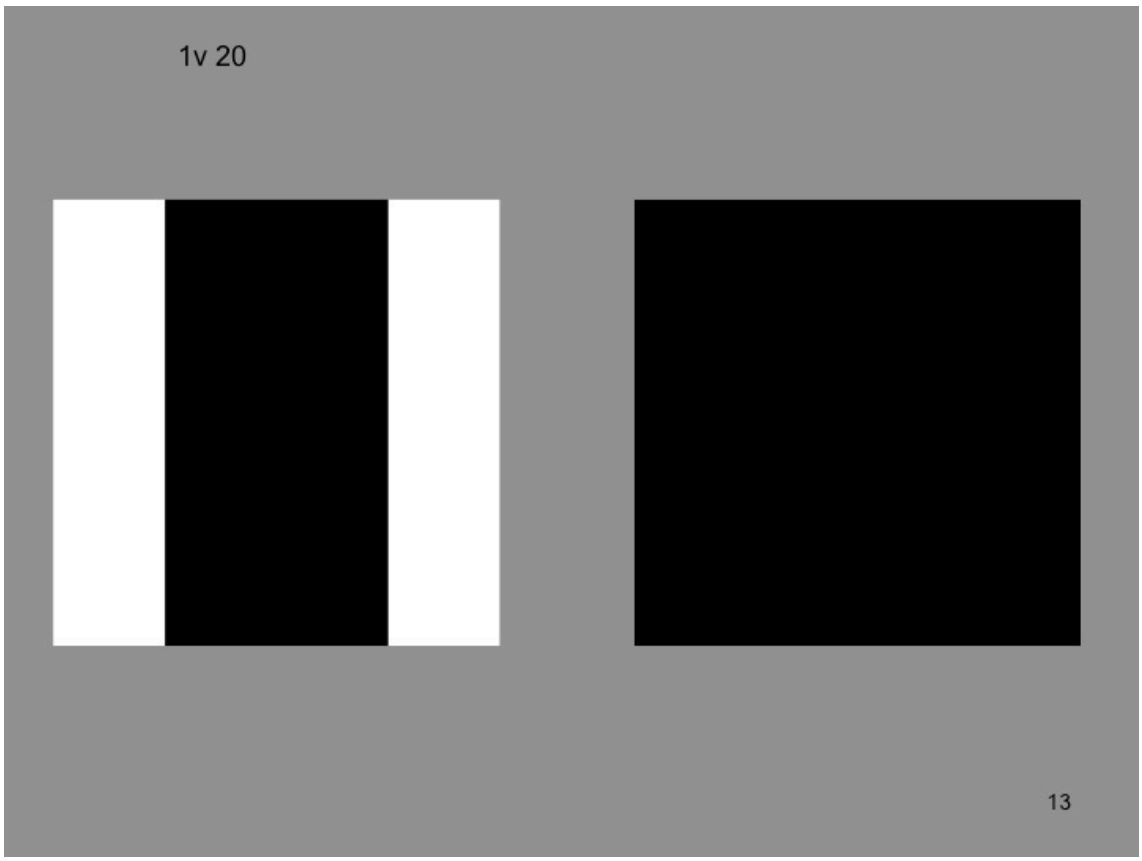
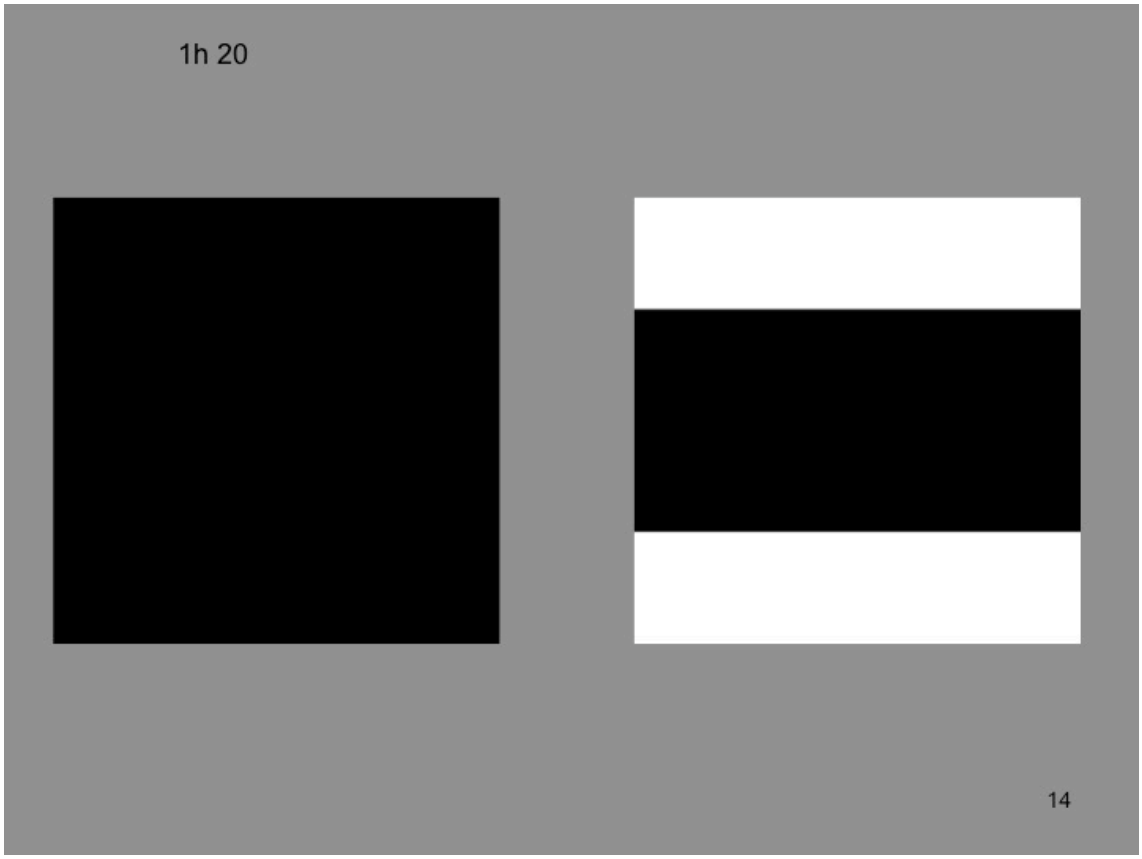

1v 20
13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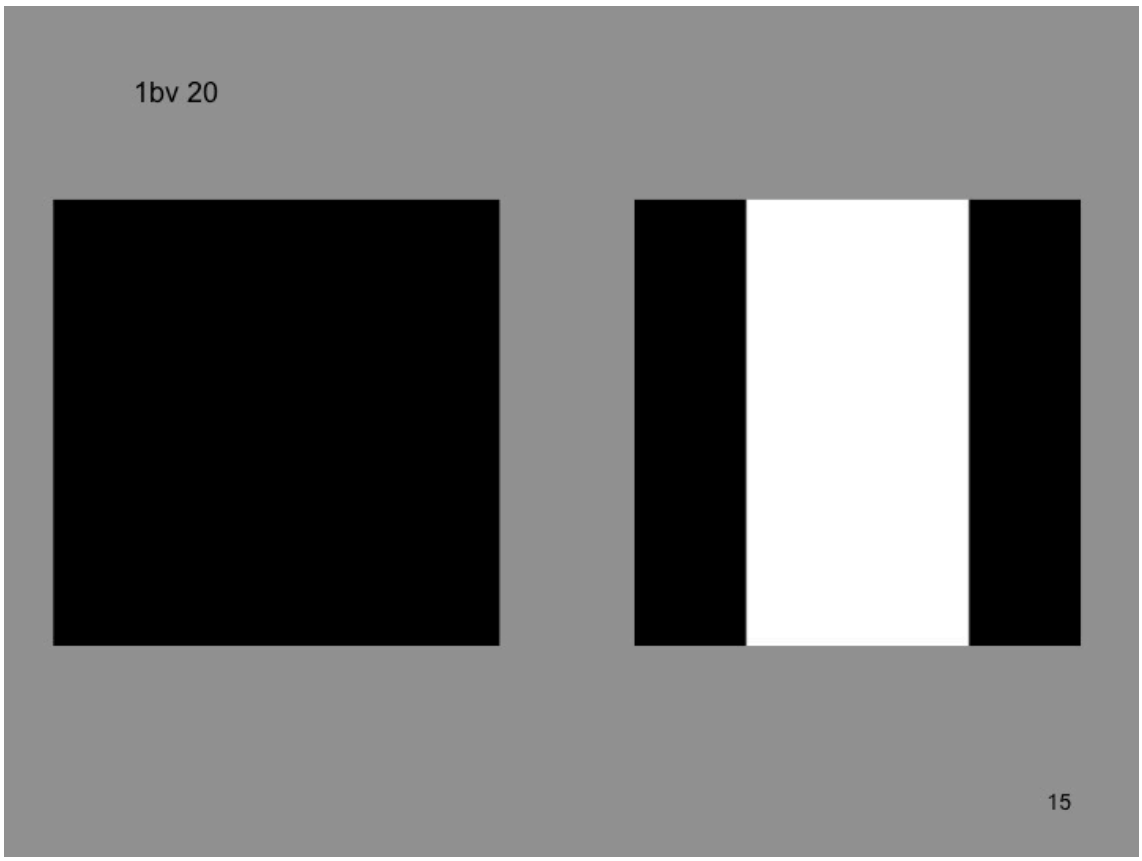
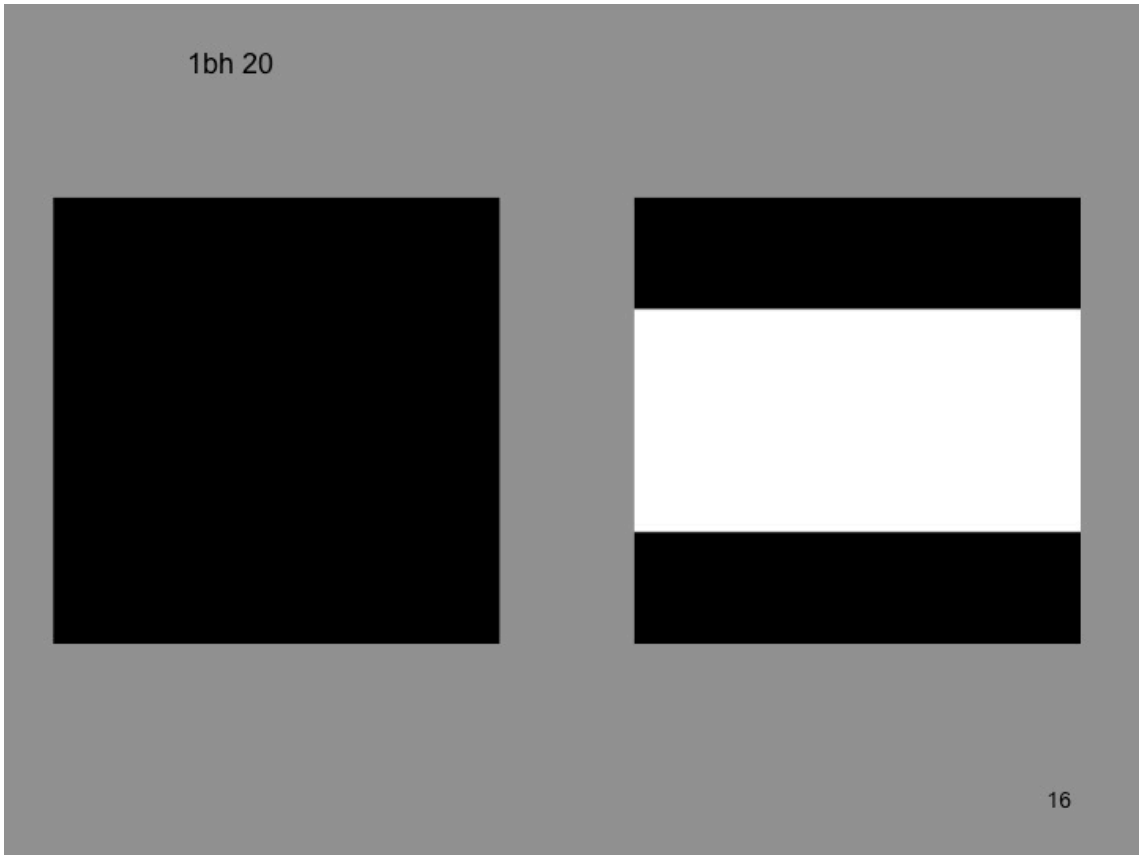
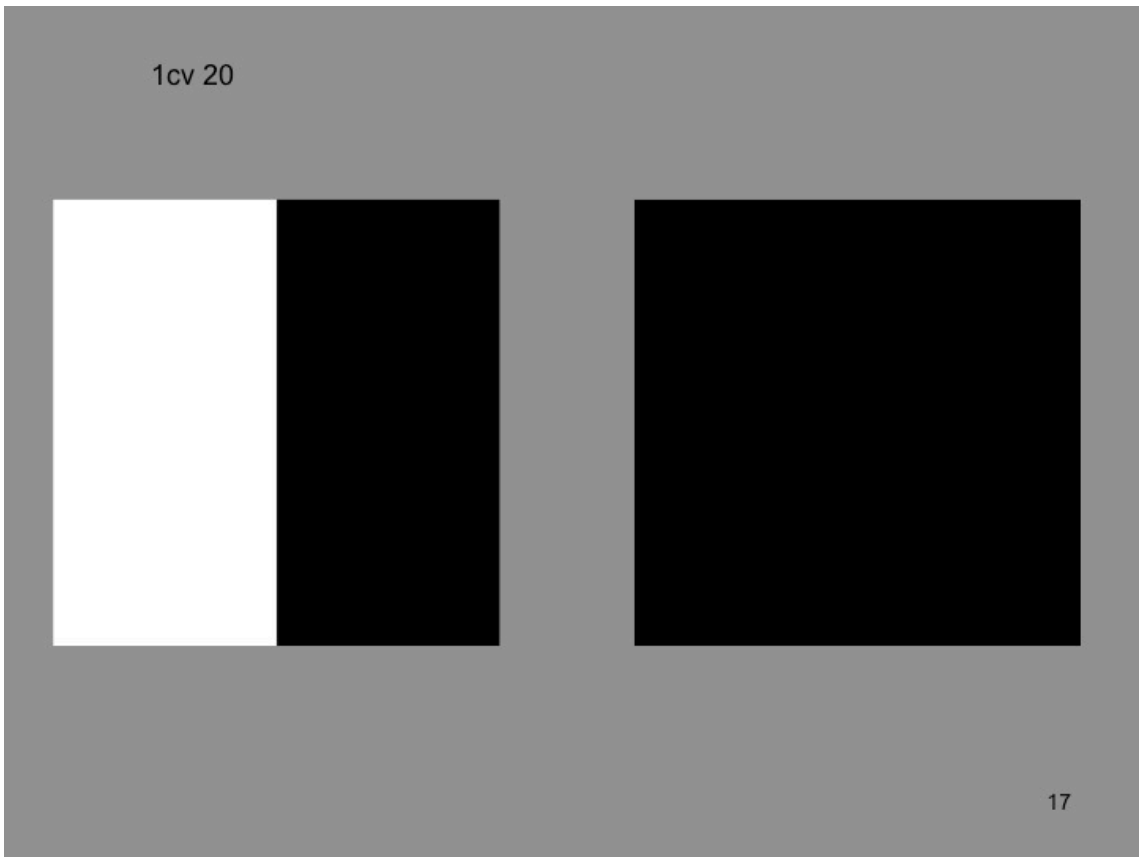
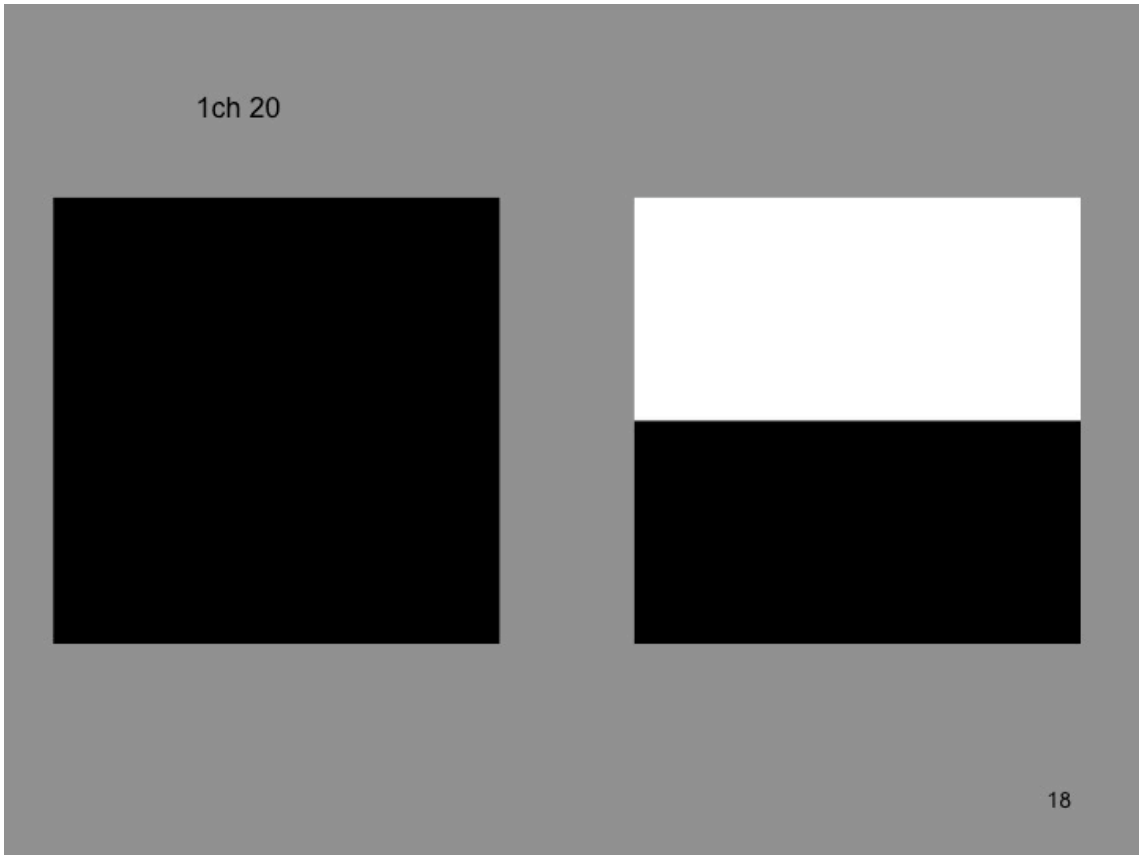
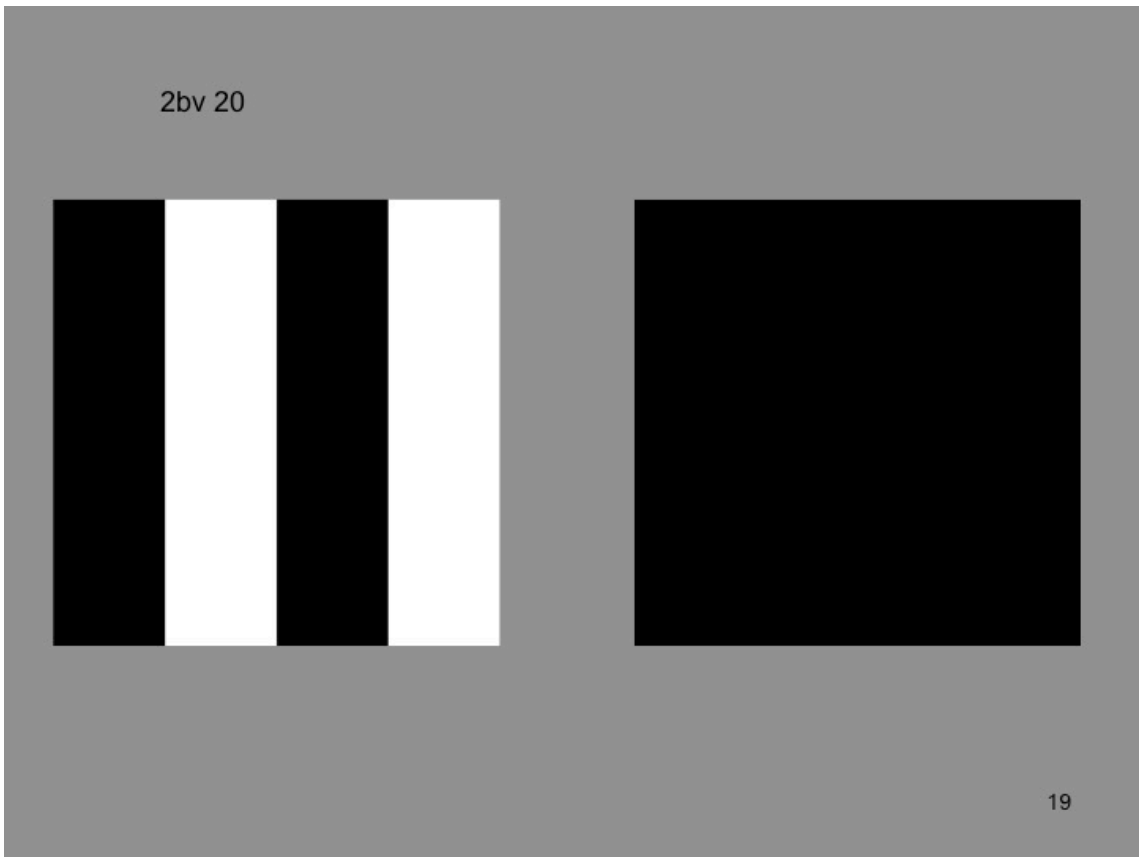
14

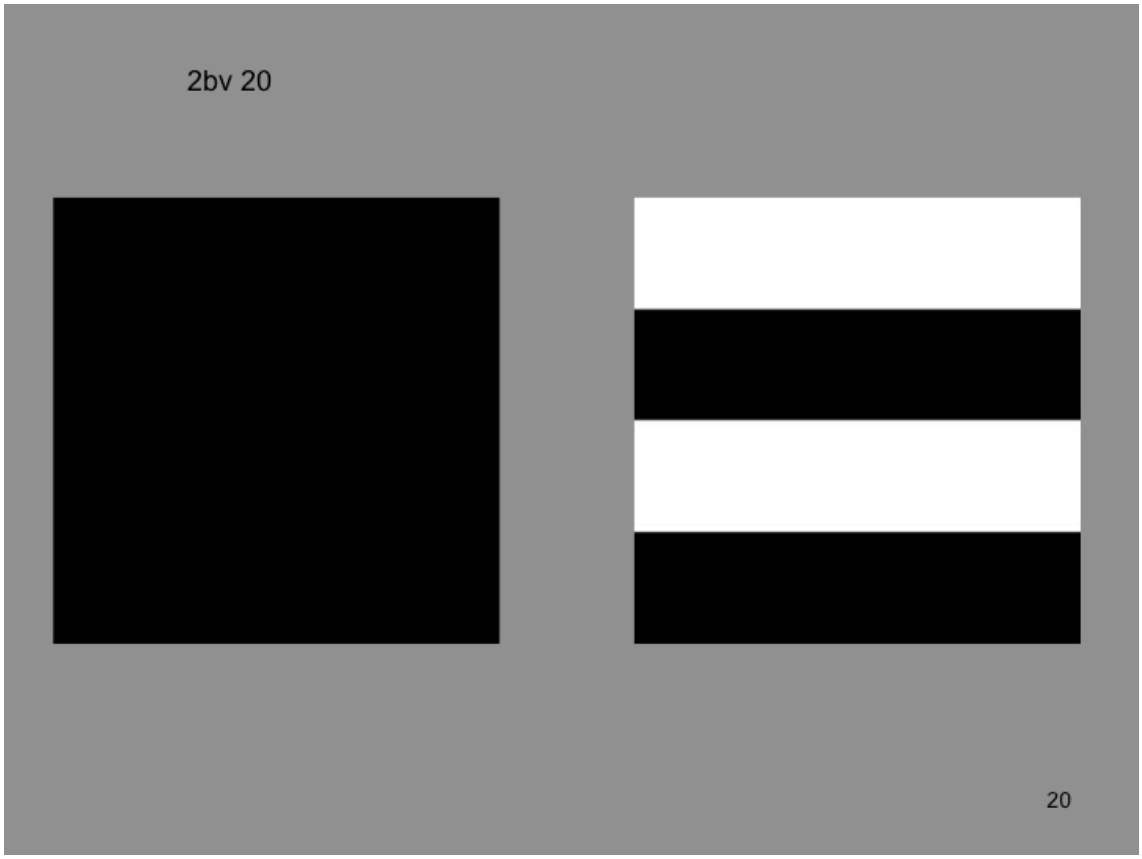

1bv 20
15

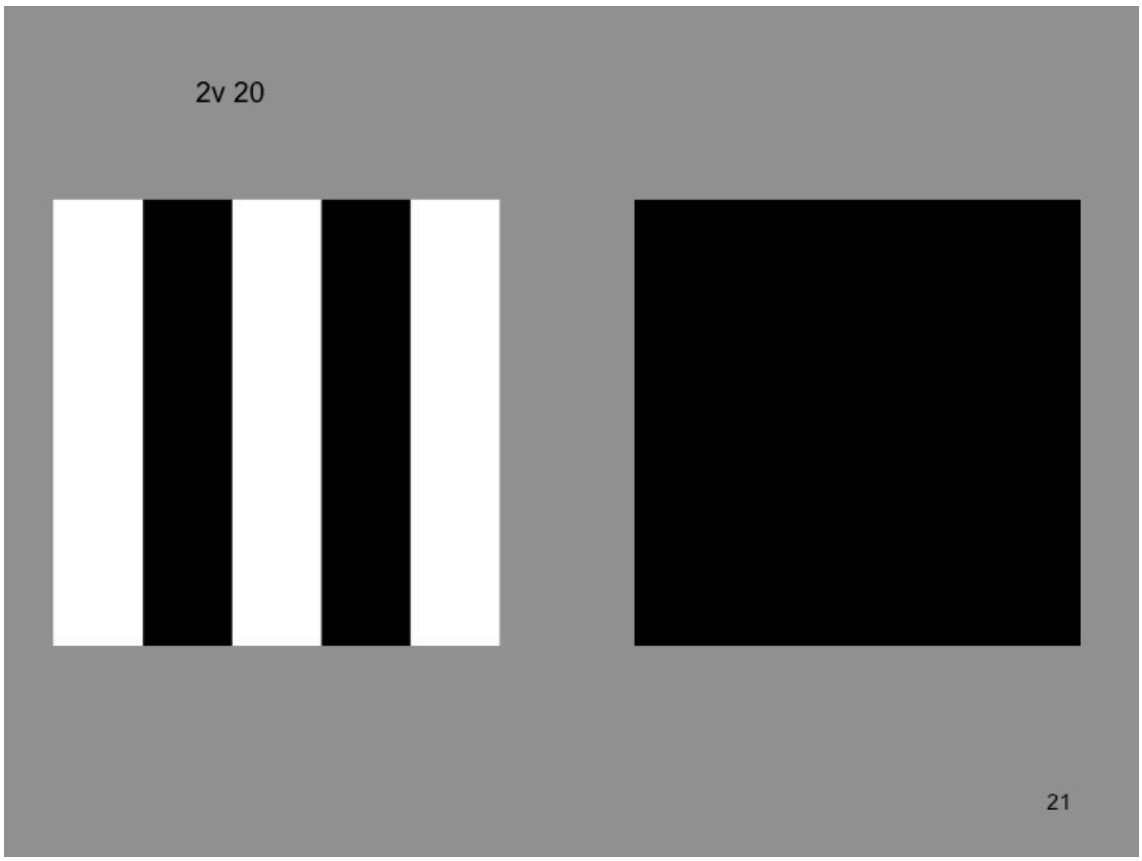

1bh 20
16

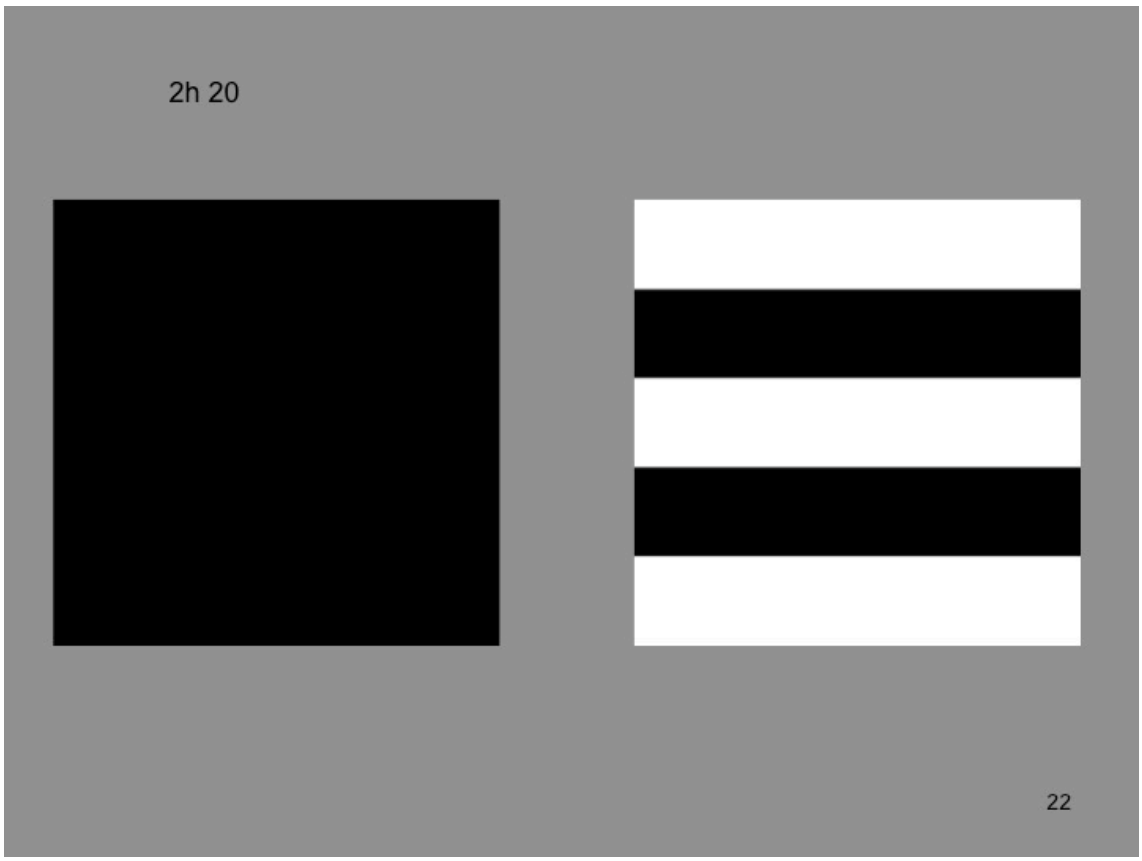

1cv 20
17


1ch 20
18


2bv 20
19


2bv 20
20


2v 20
21


2h 20
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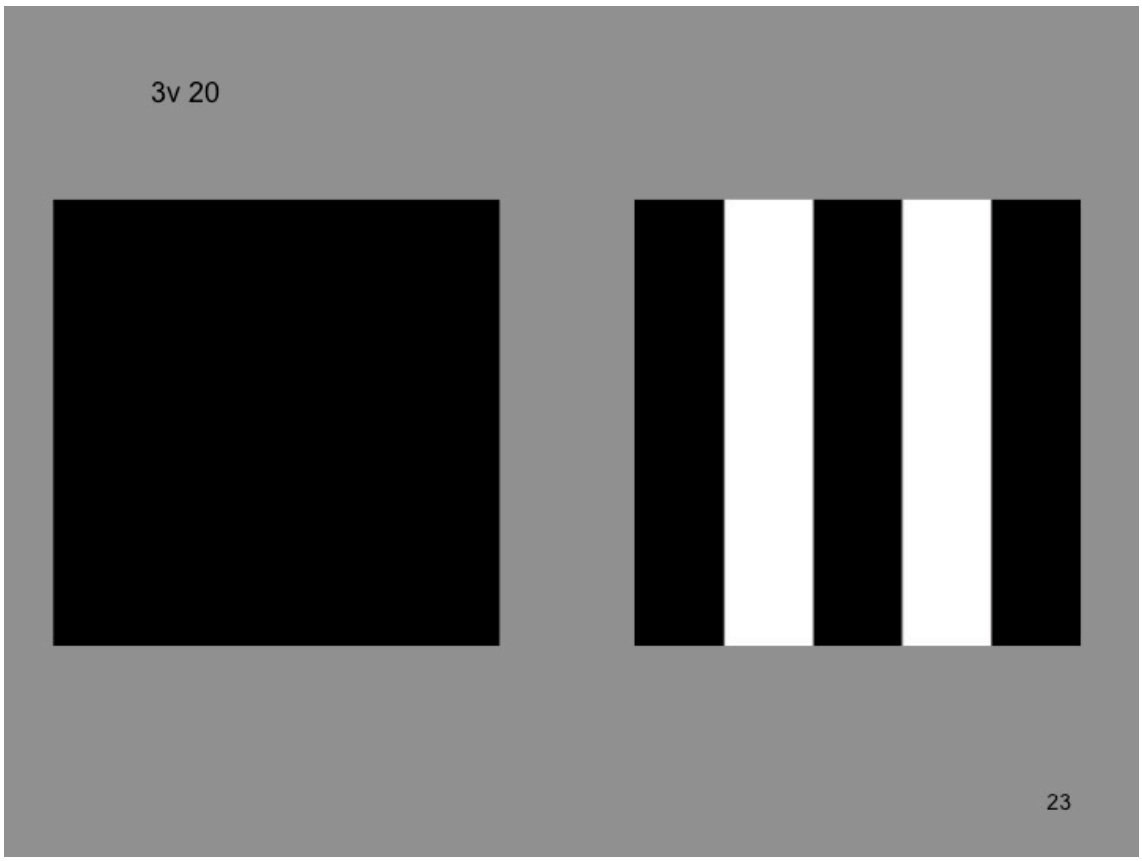
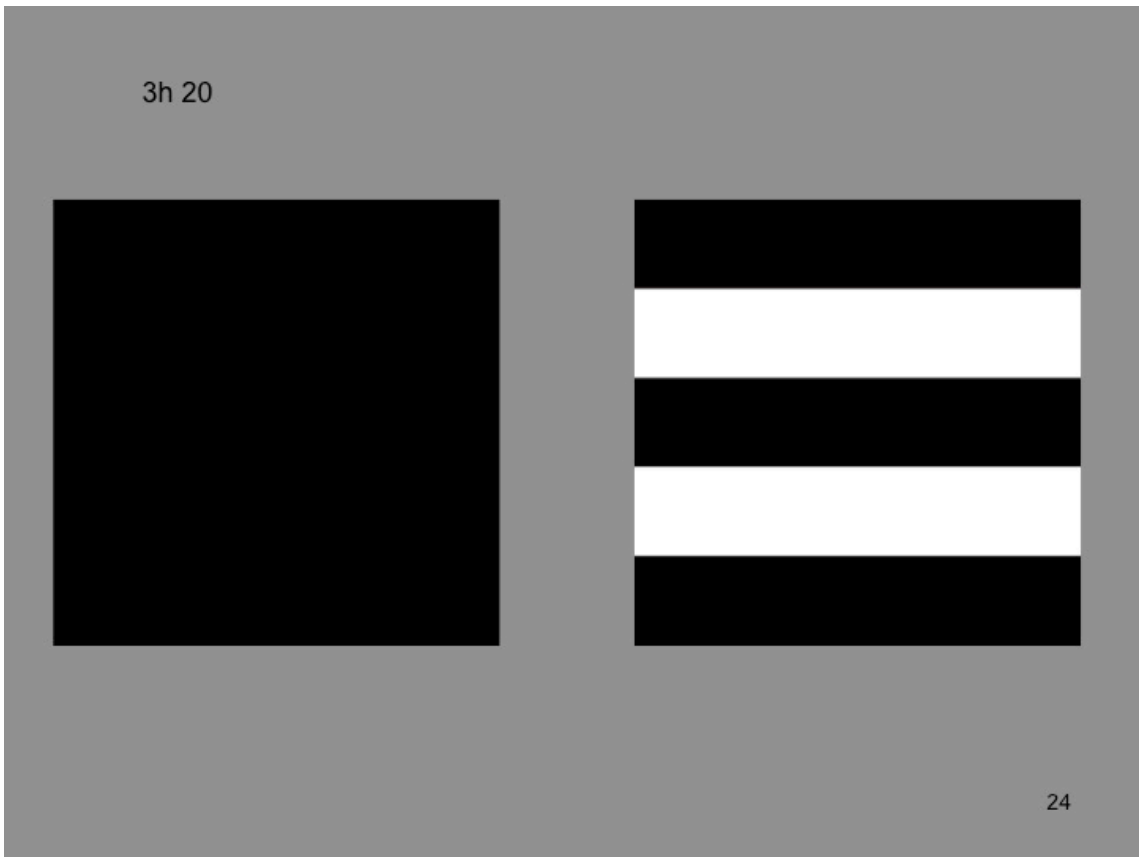
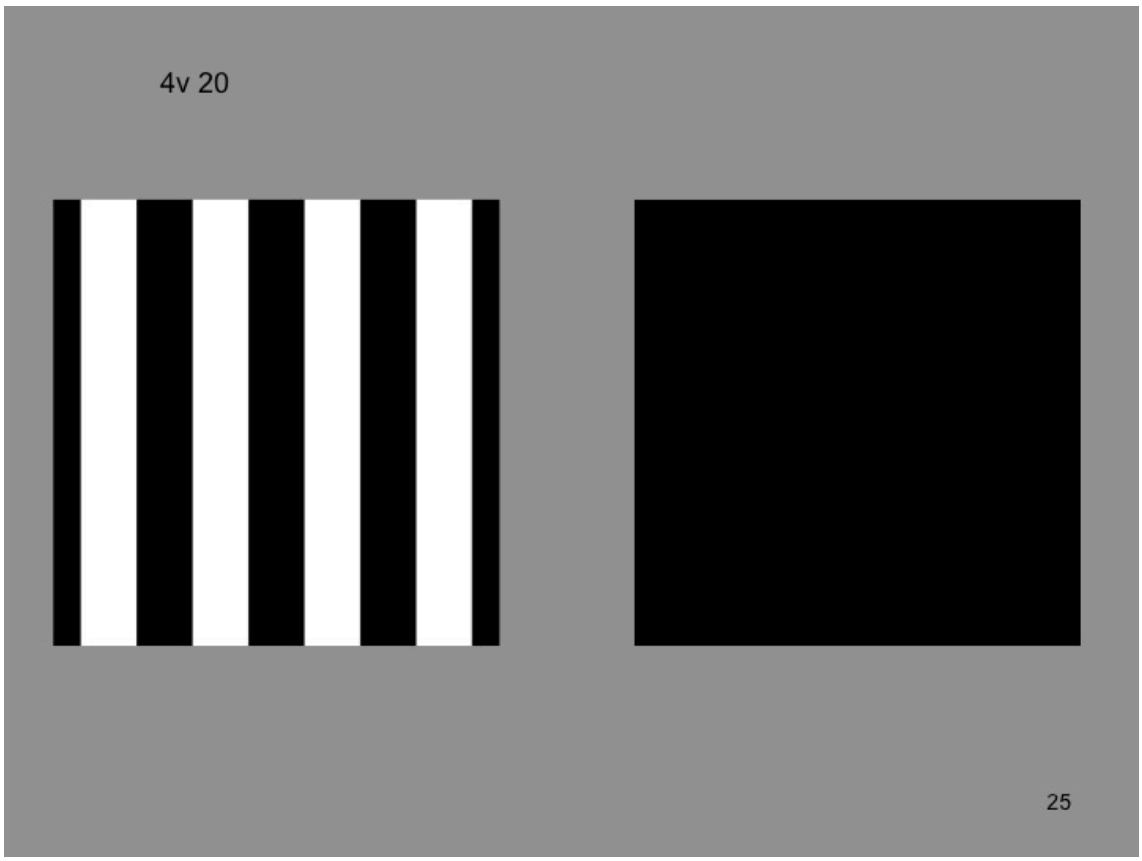
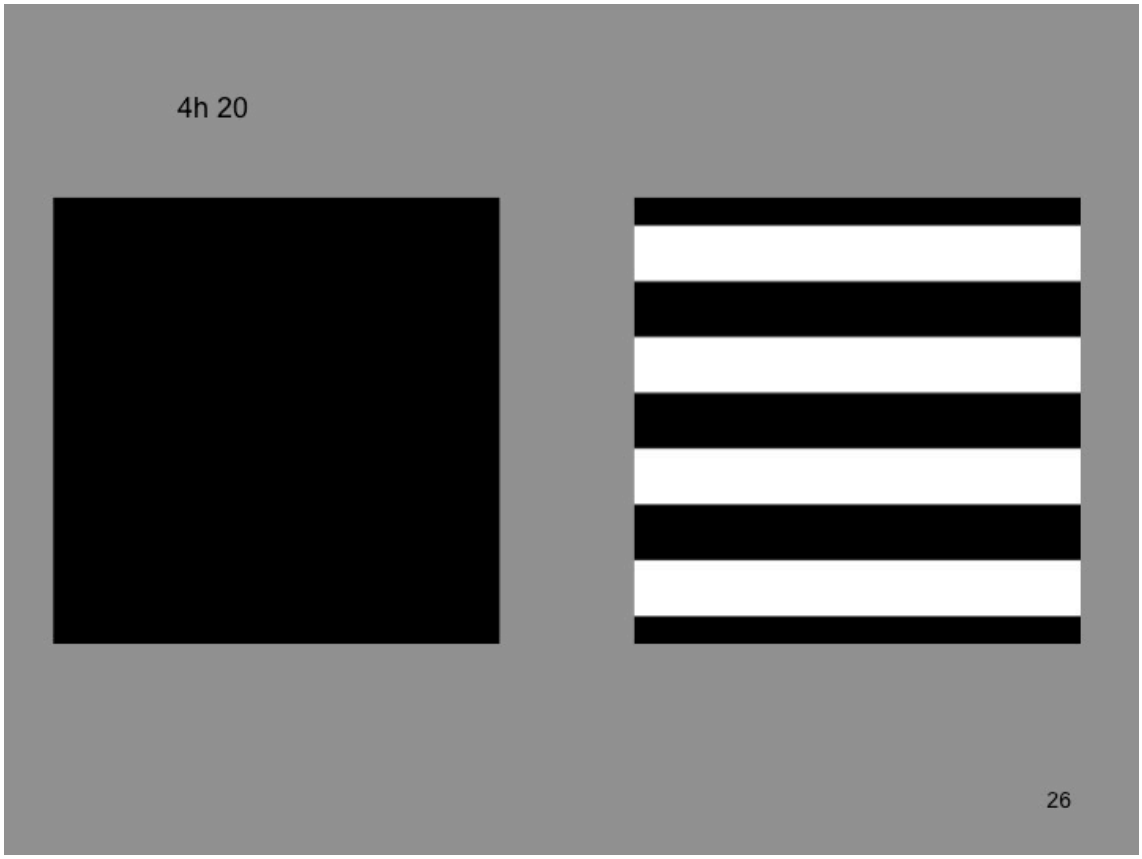
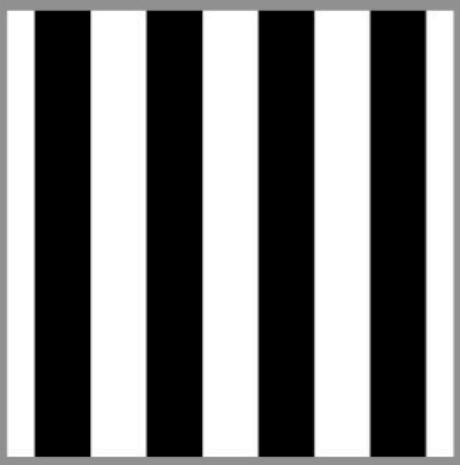

3v 20
23

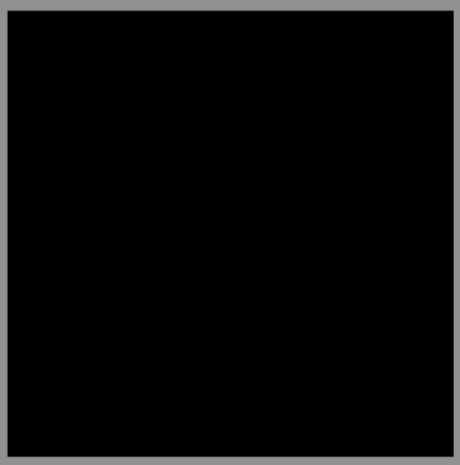

3h 20
24


4v 20
25


4h 20
26

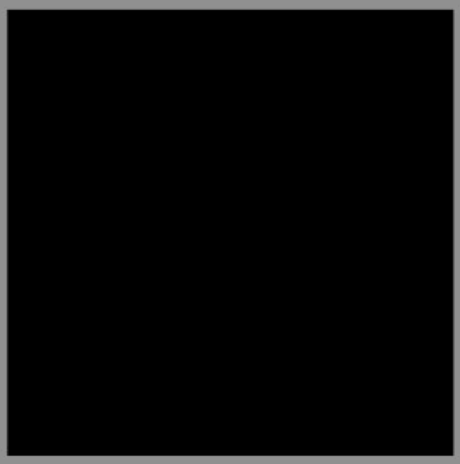
4bv 20

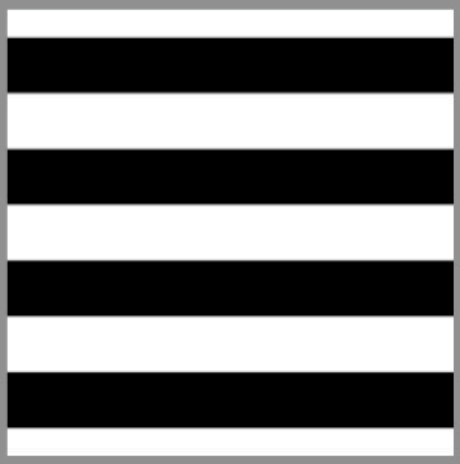




27

4bh 20





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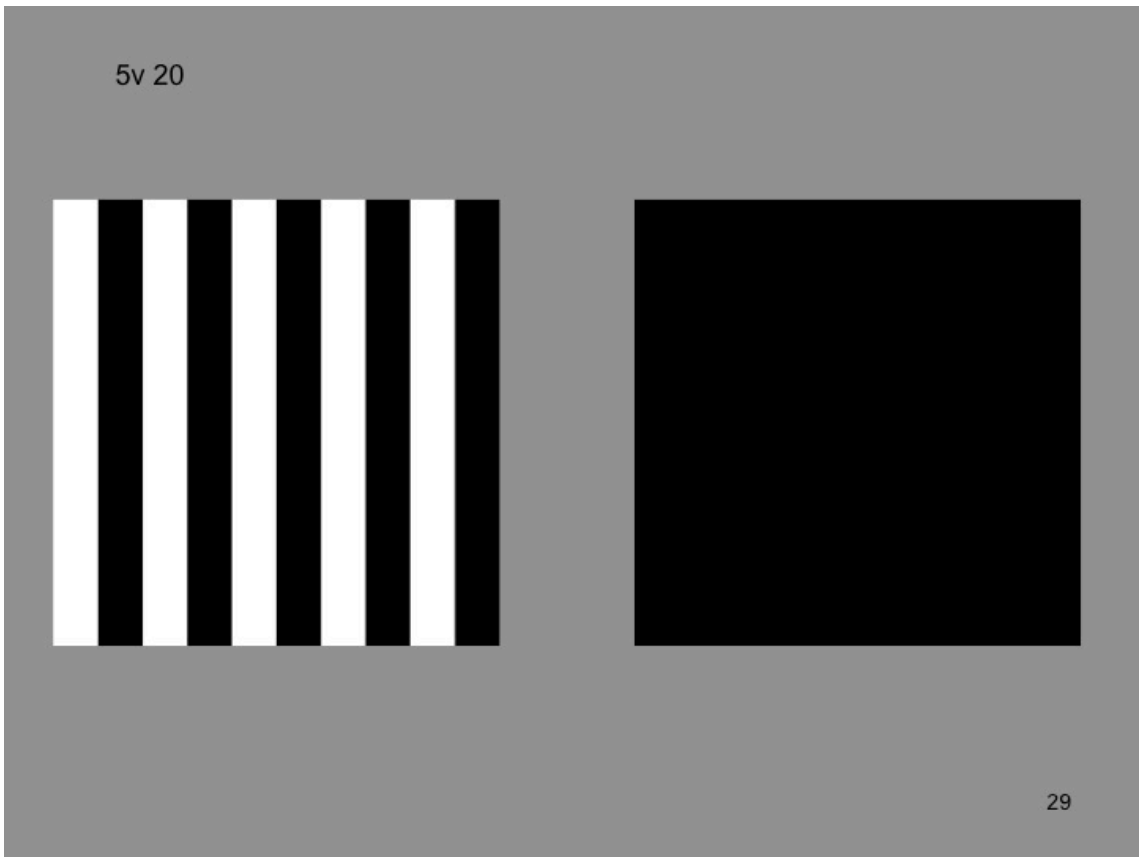
5v 20
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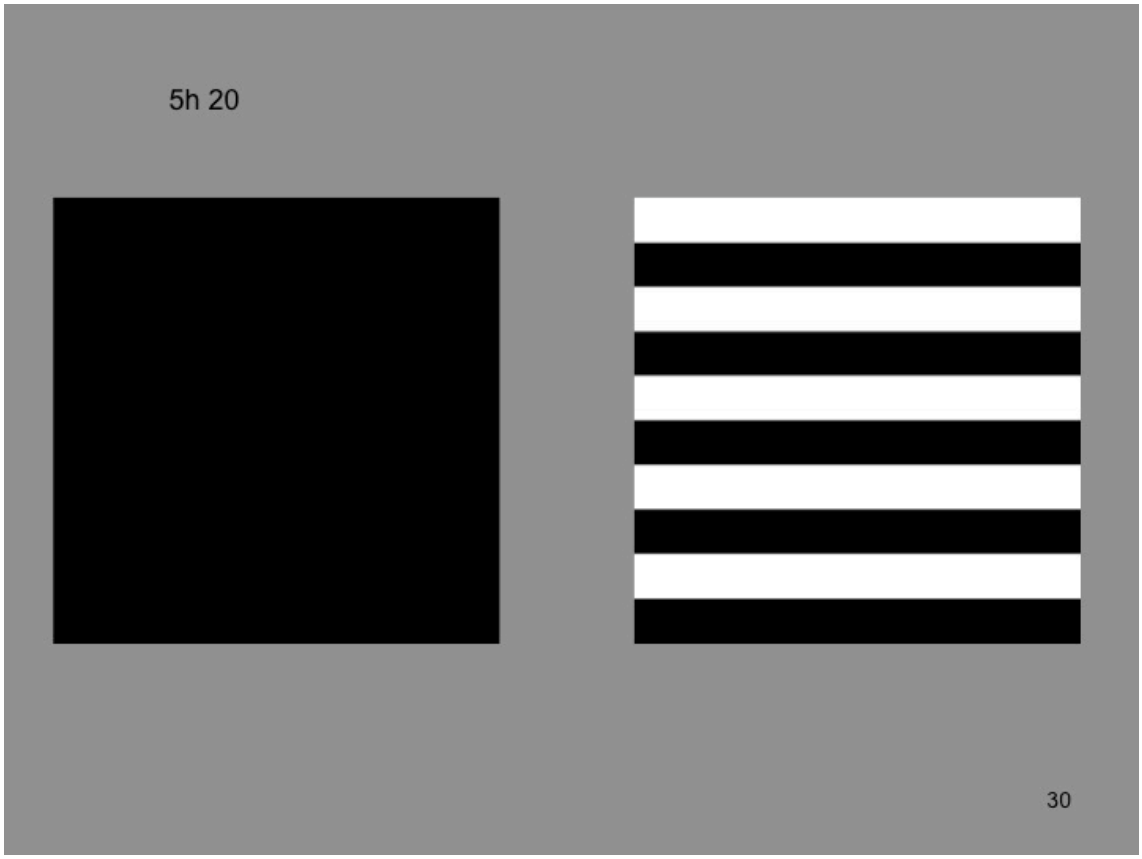
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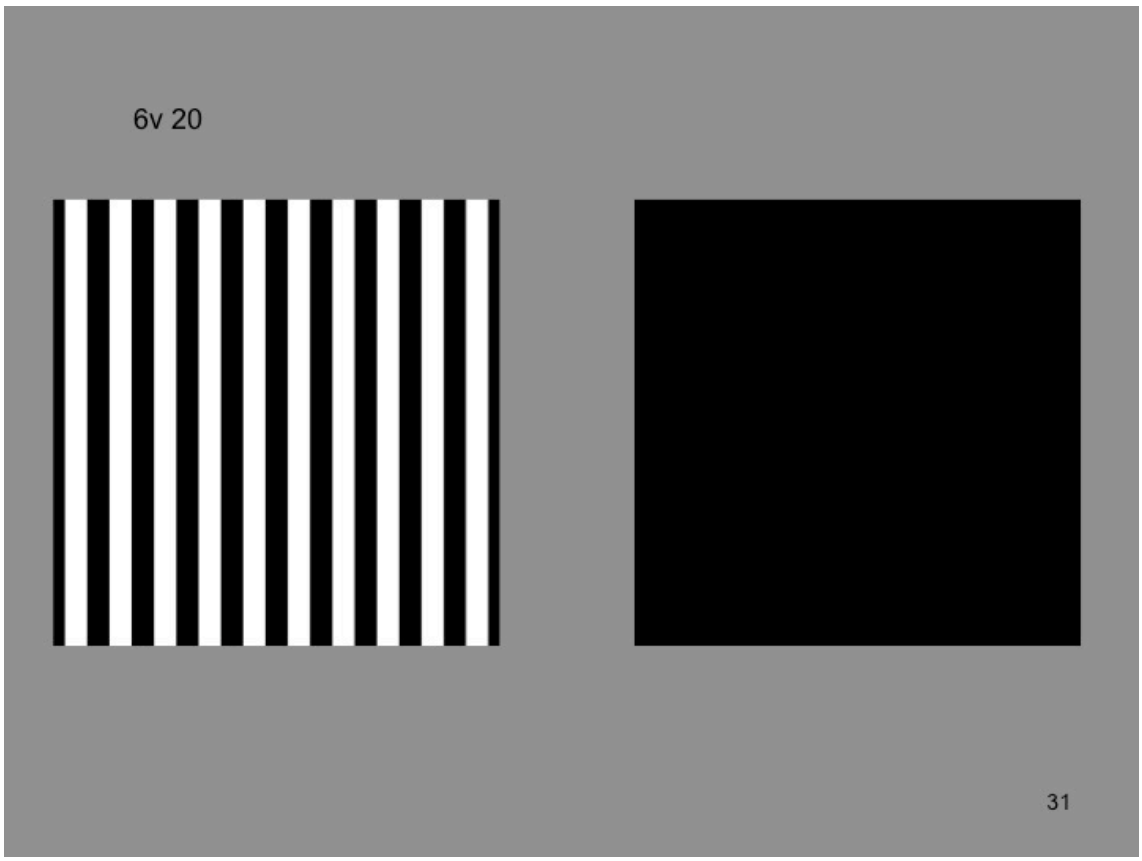
6v 20
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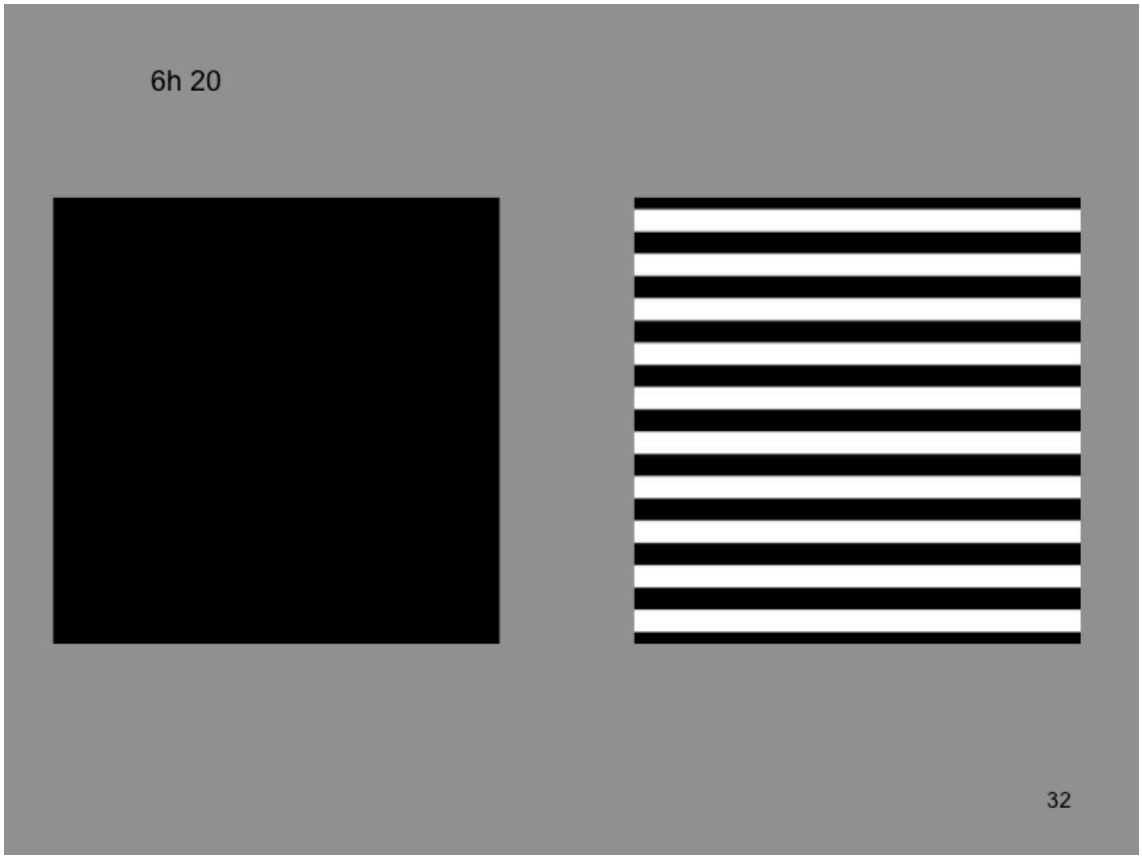
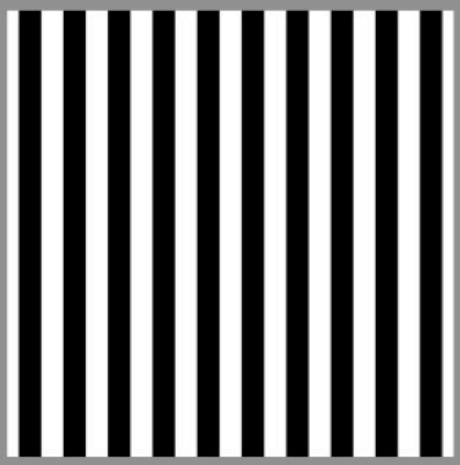
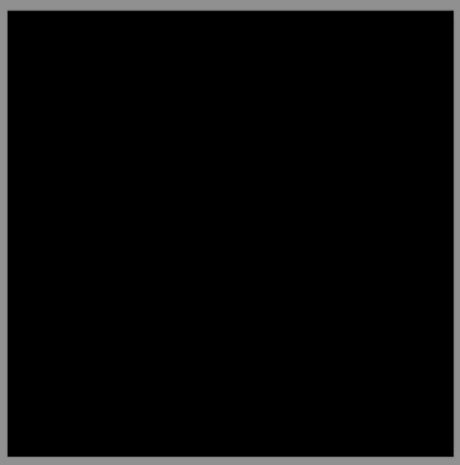

6h 20
32

6bv 20





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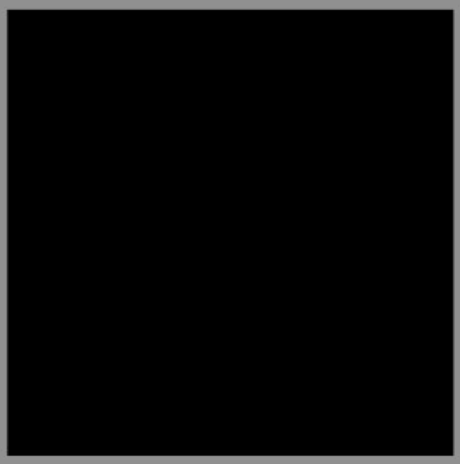
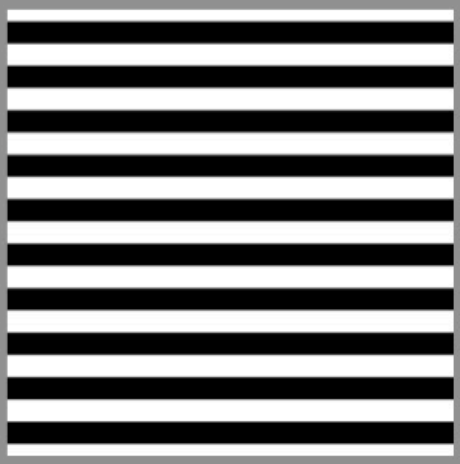
6bh 20





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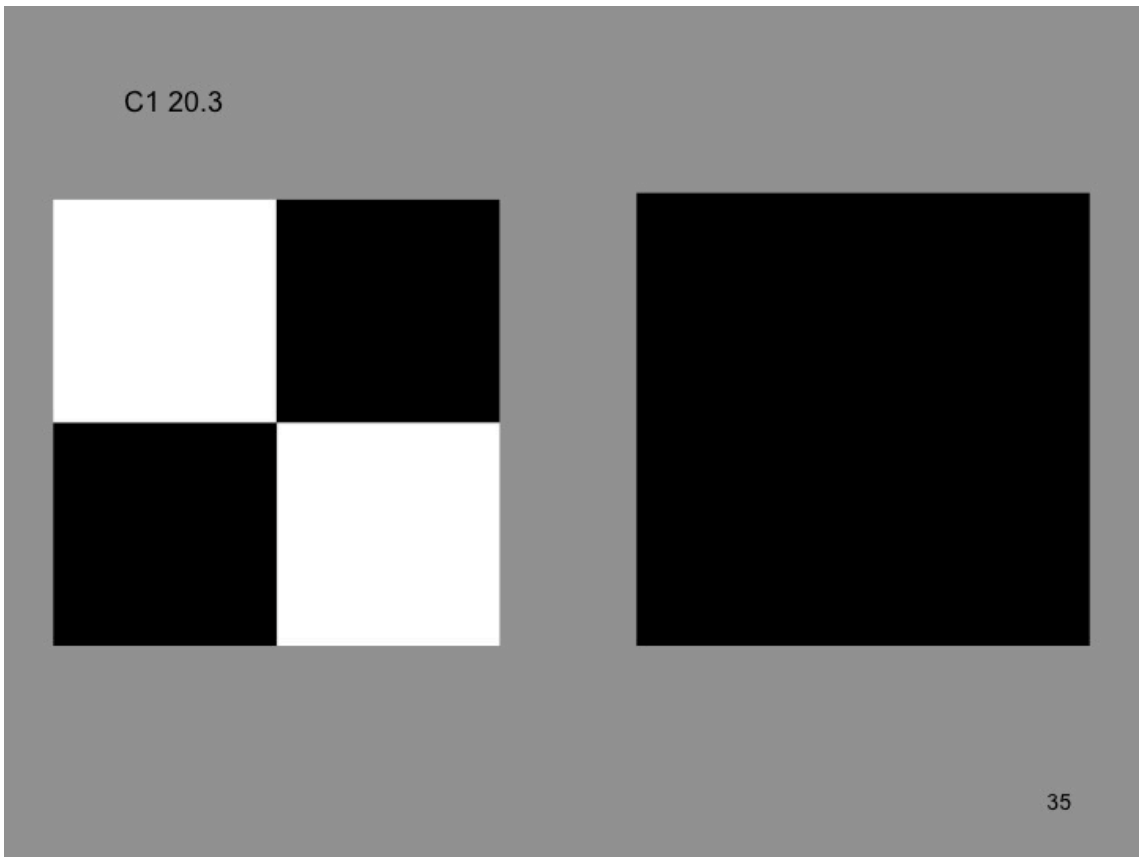
C1 20.3
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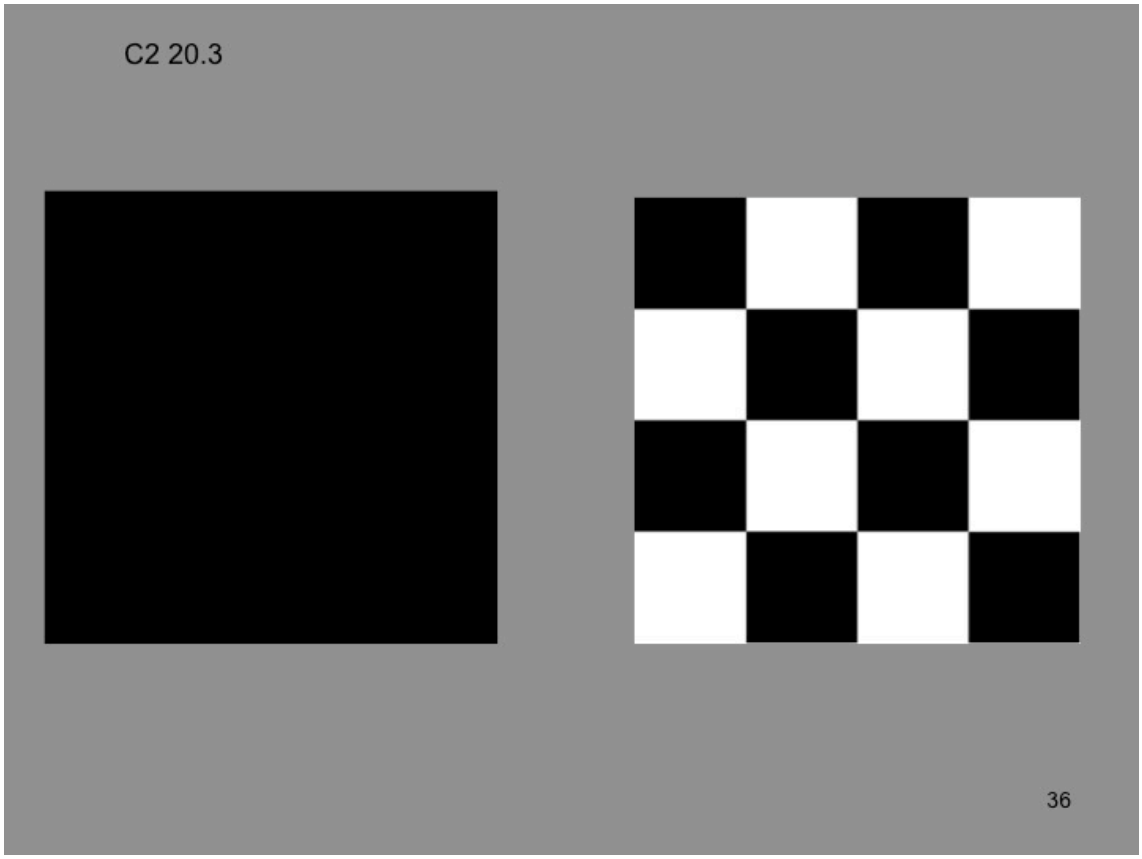
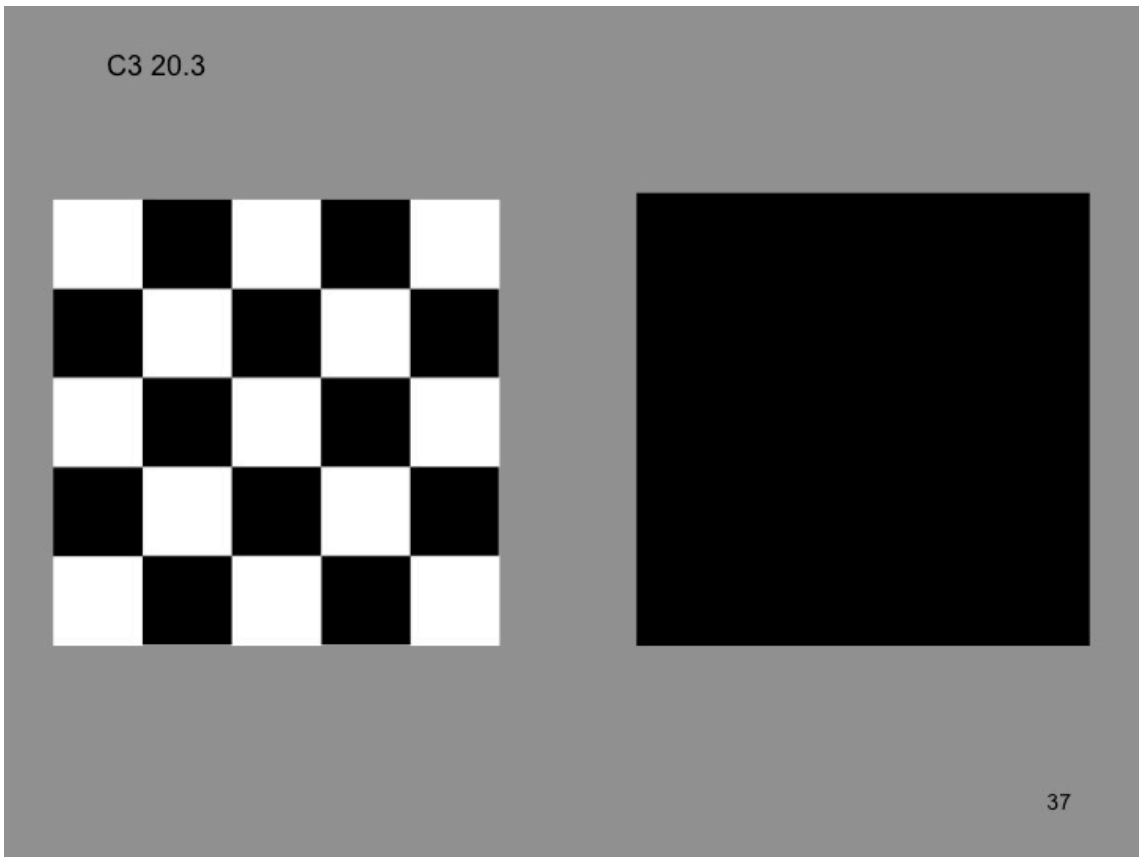

C2 20.3
36


C3 20.3
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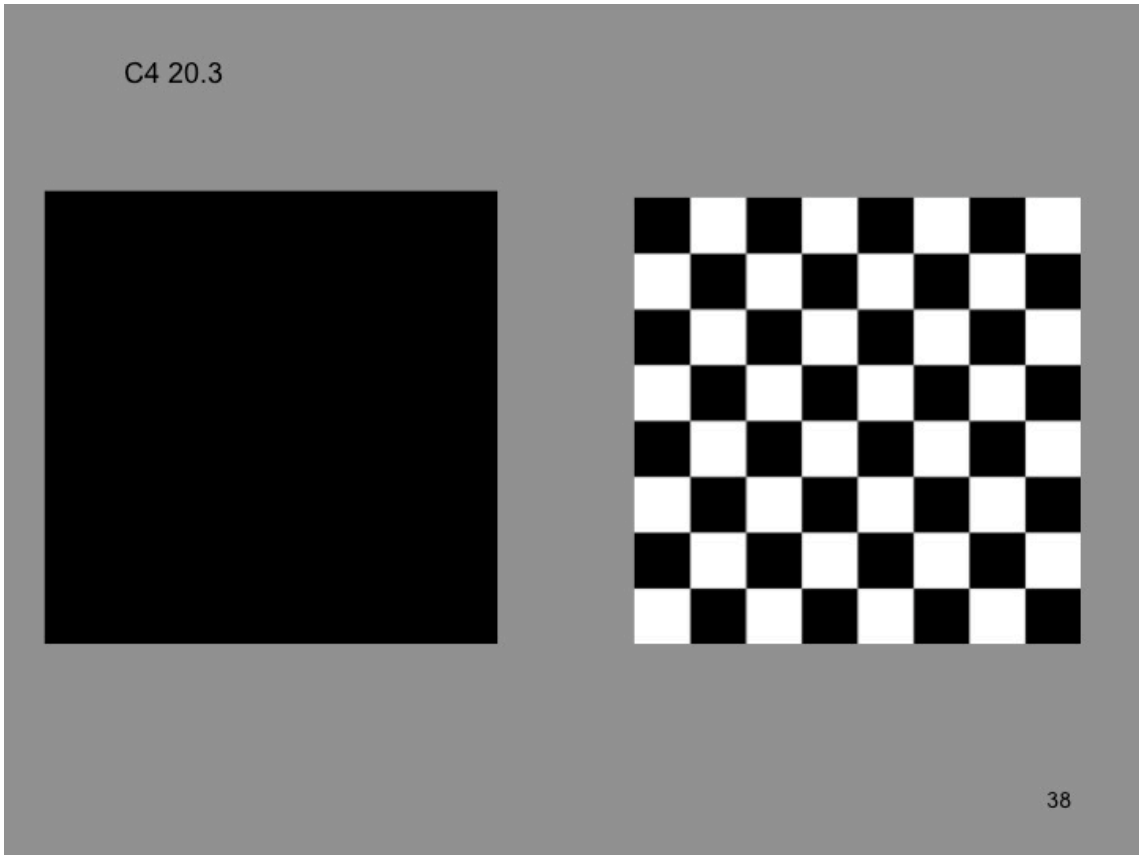
C4 20.3
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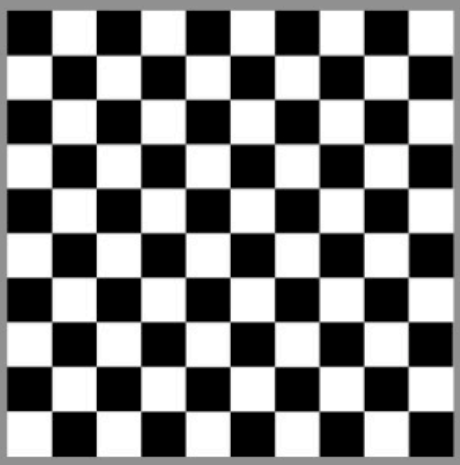
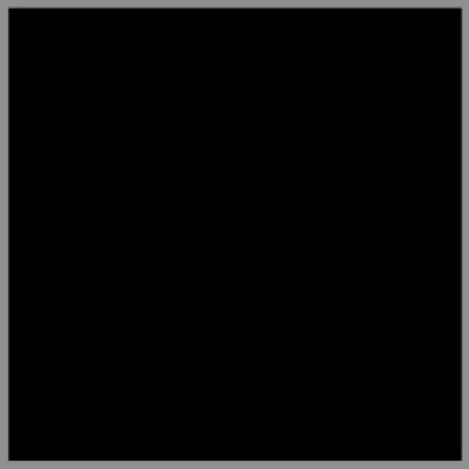
C5 20.3





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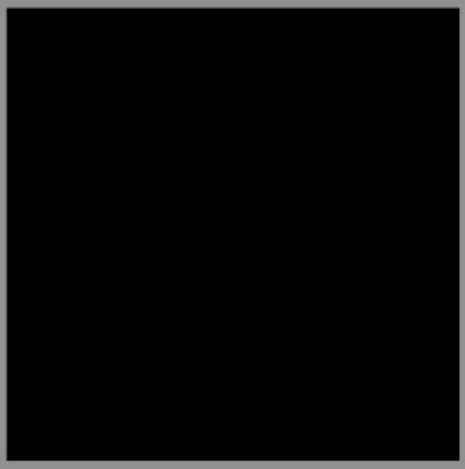
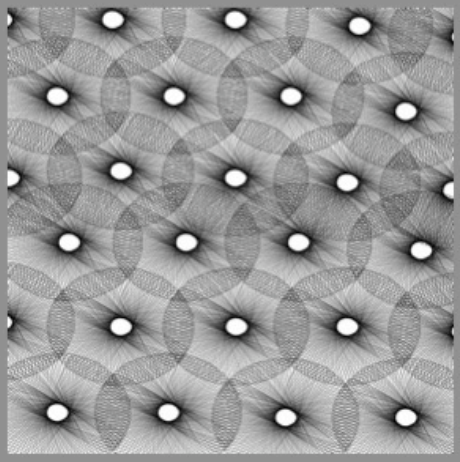
S2 20.3





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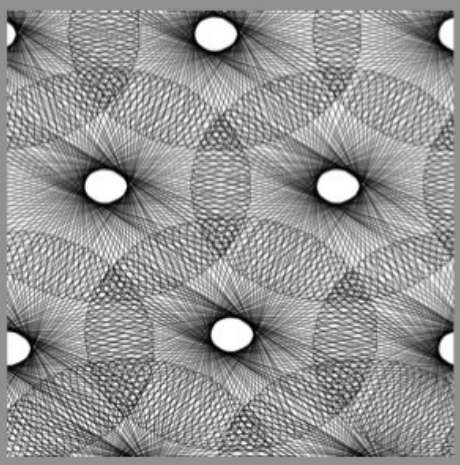
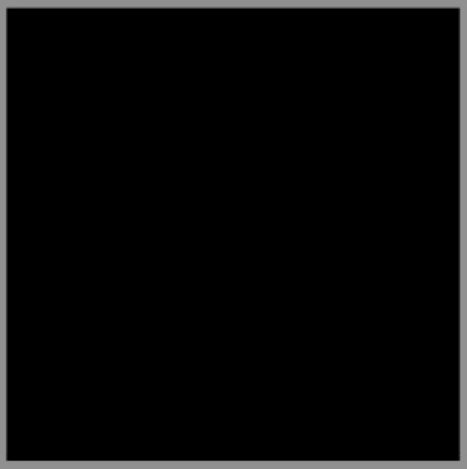
S3 20.3





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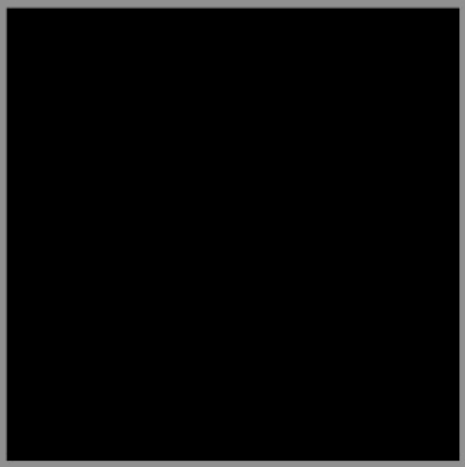
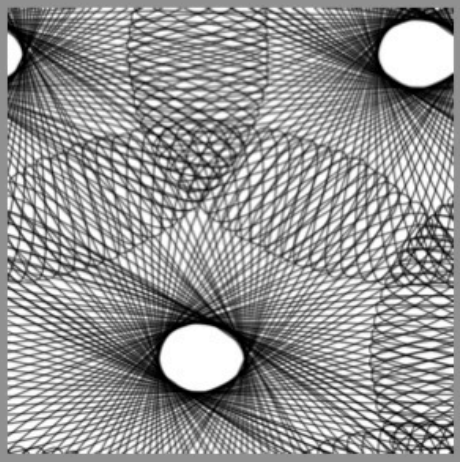
S4 20.3





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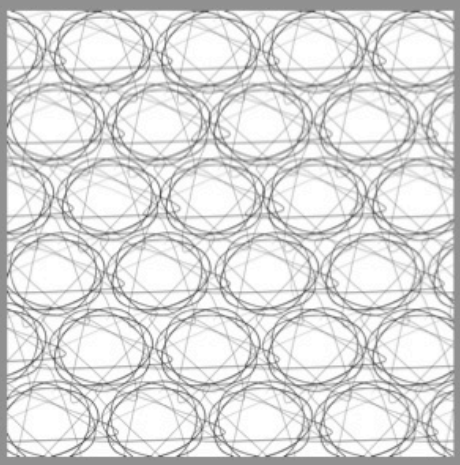
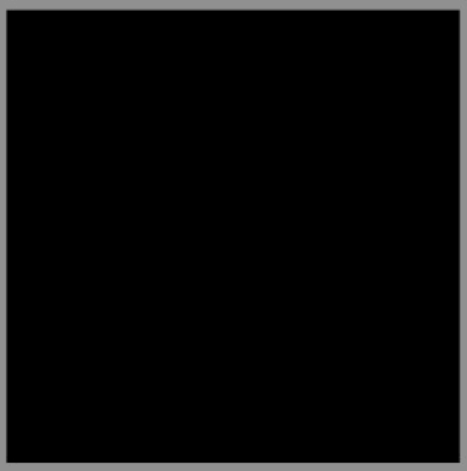
S5 20.3





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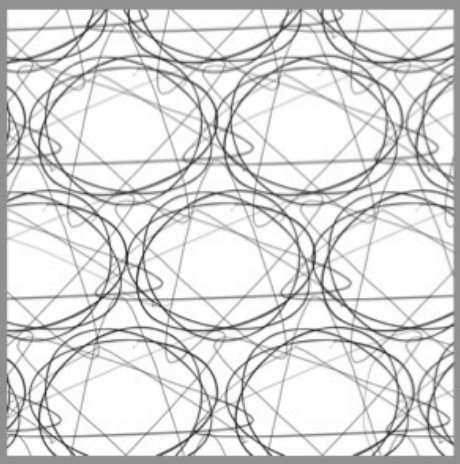
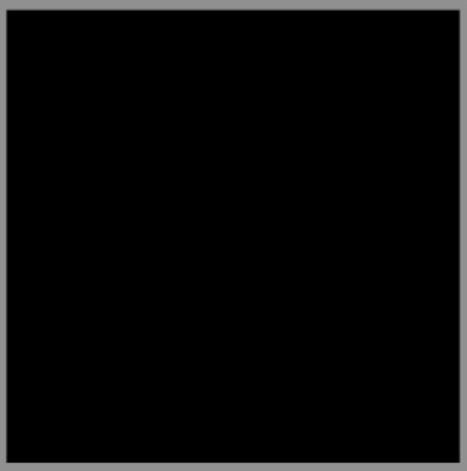
S6 20.3





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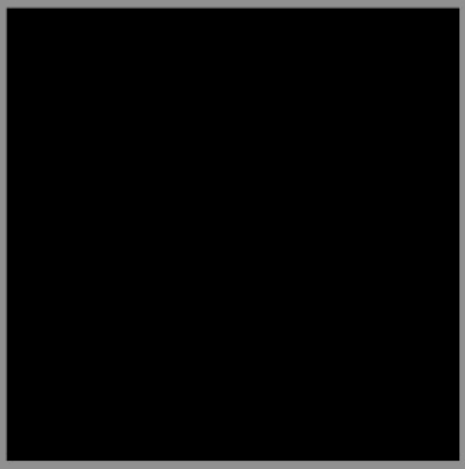
S7 20.3



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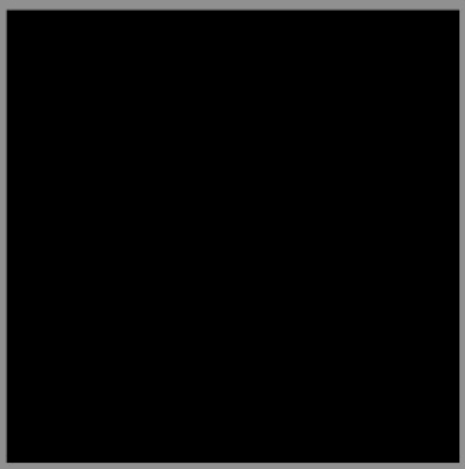
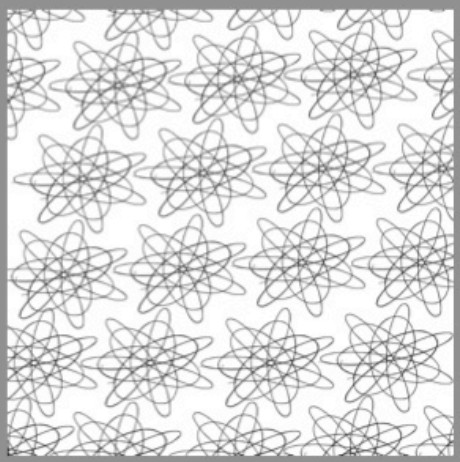
S8 20.3





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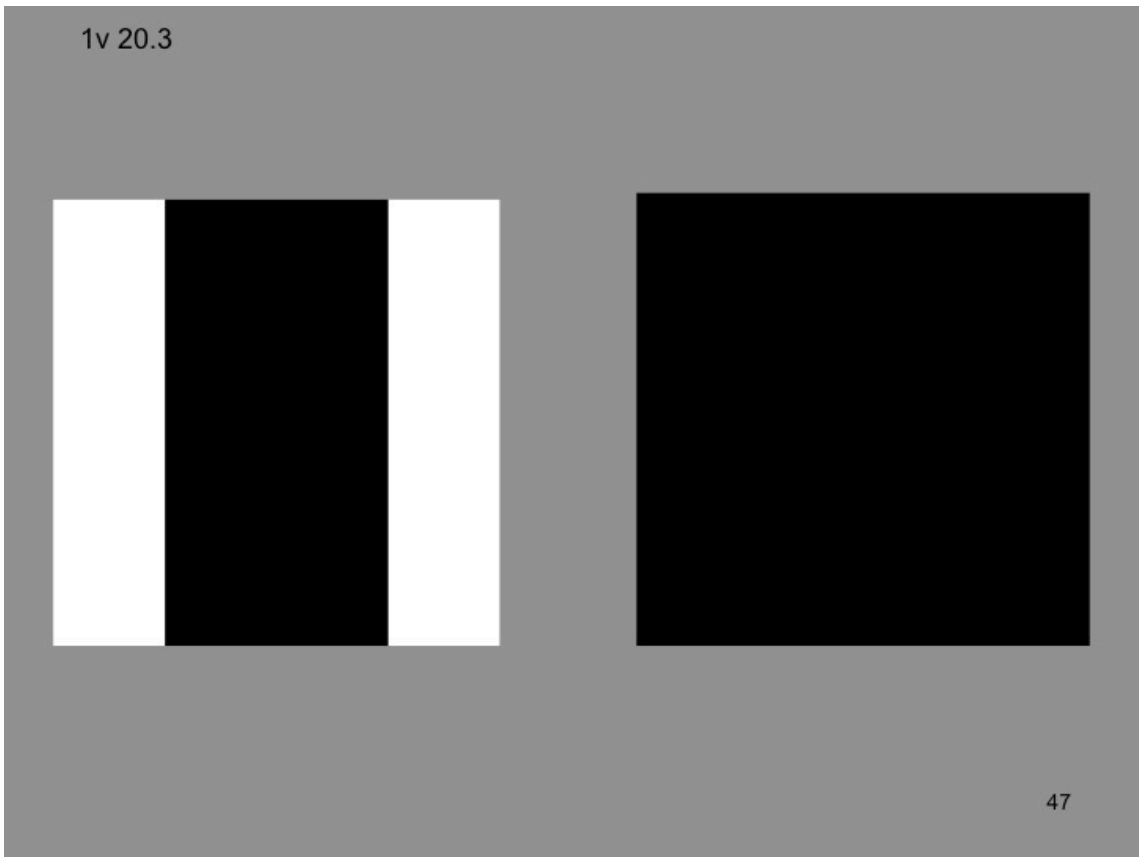
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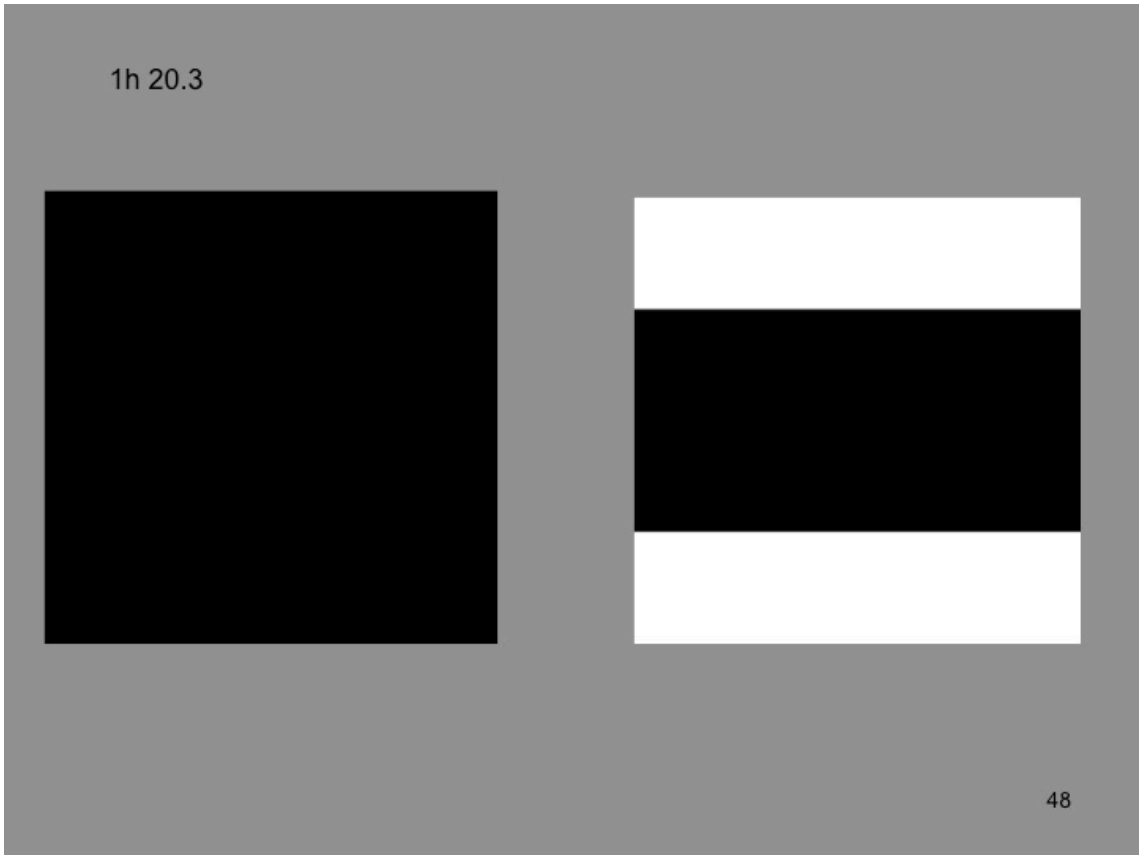
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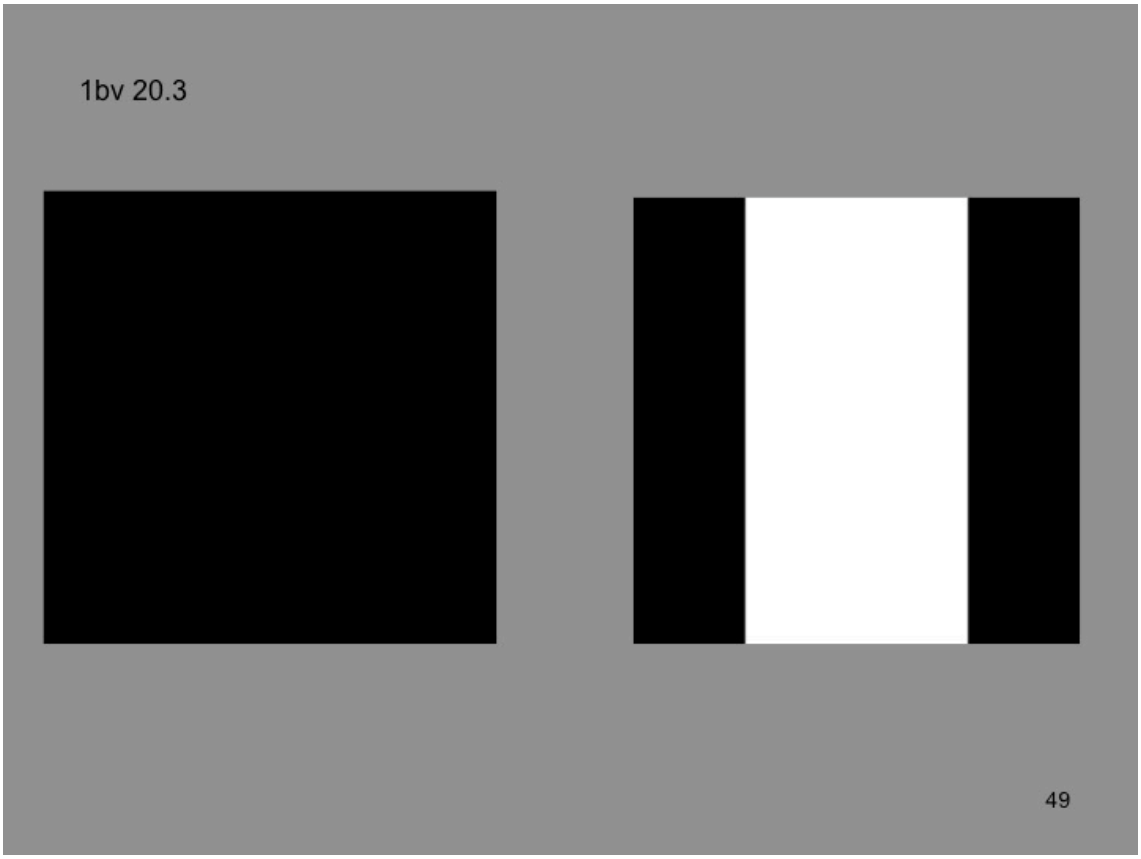
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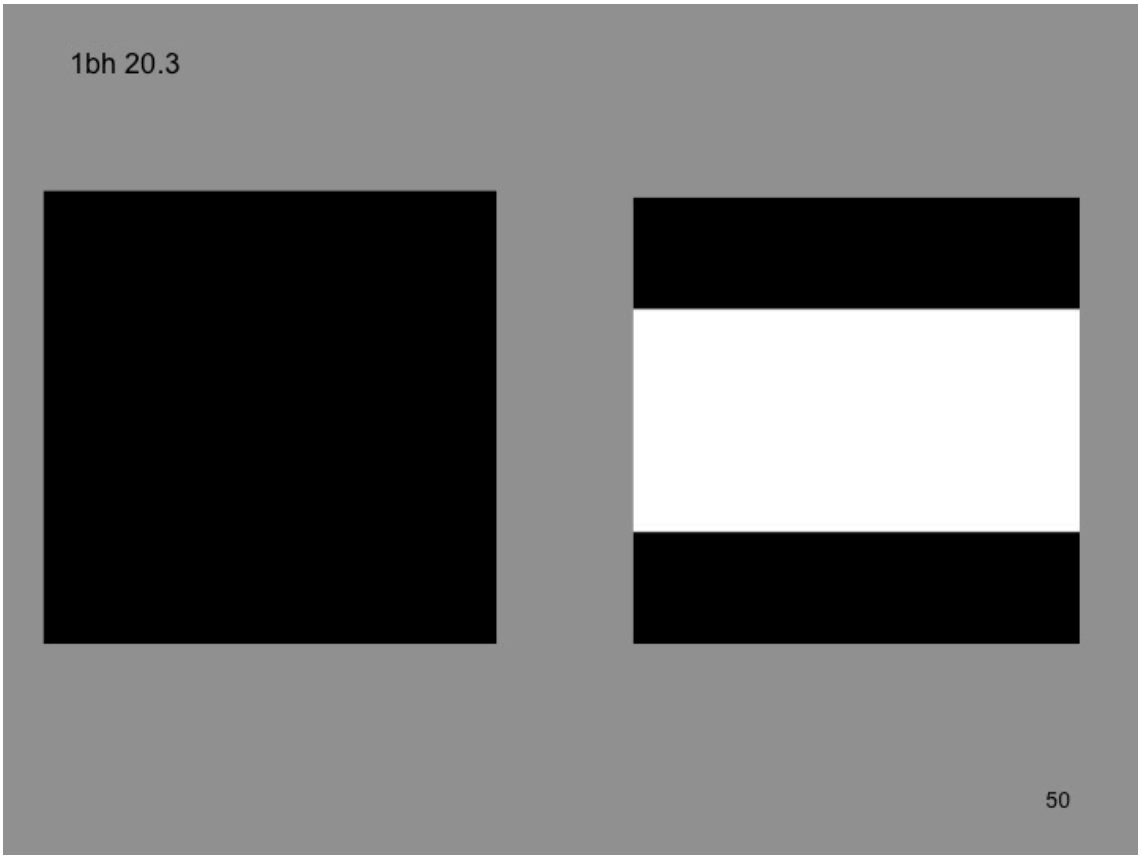
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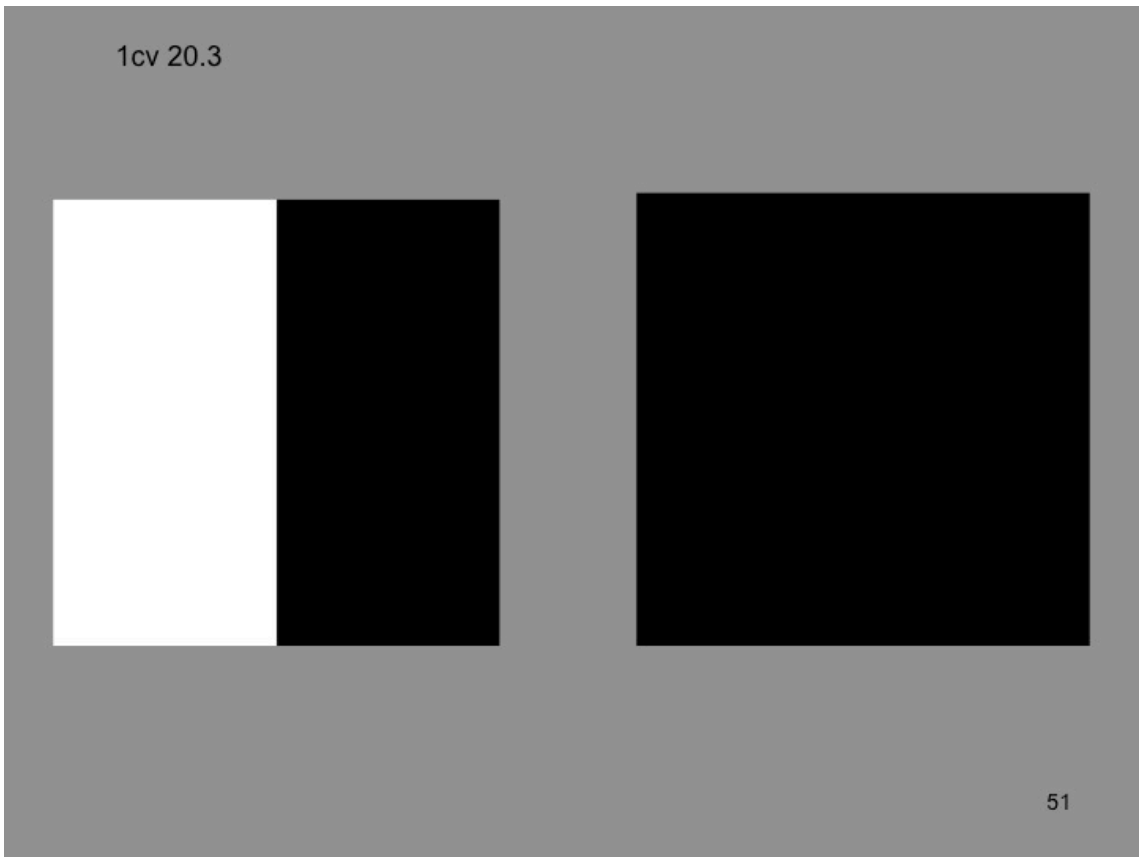
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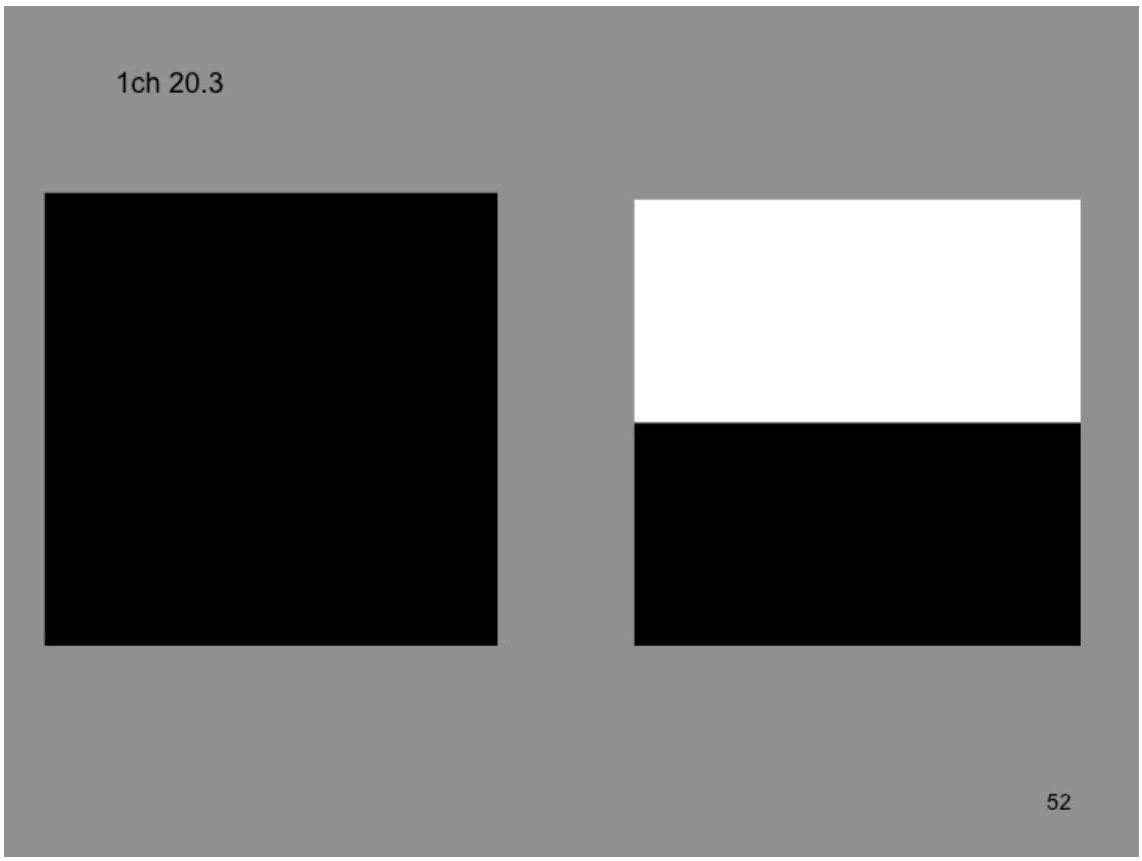
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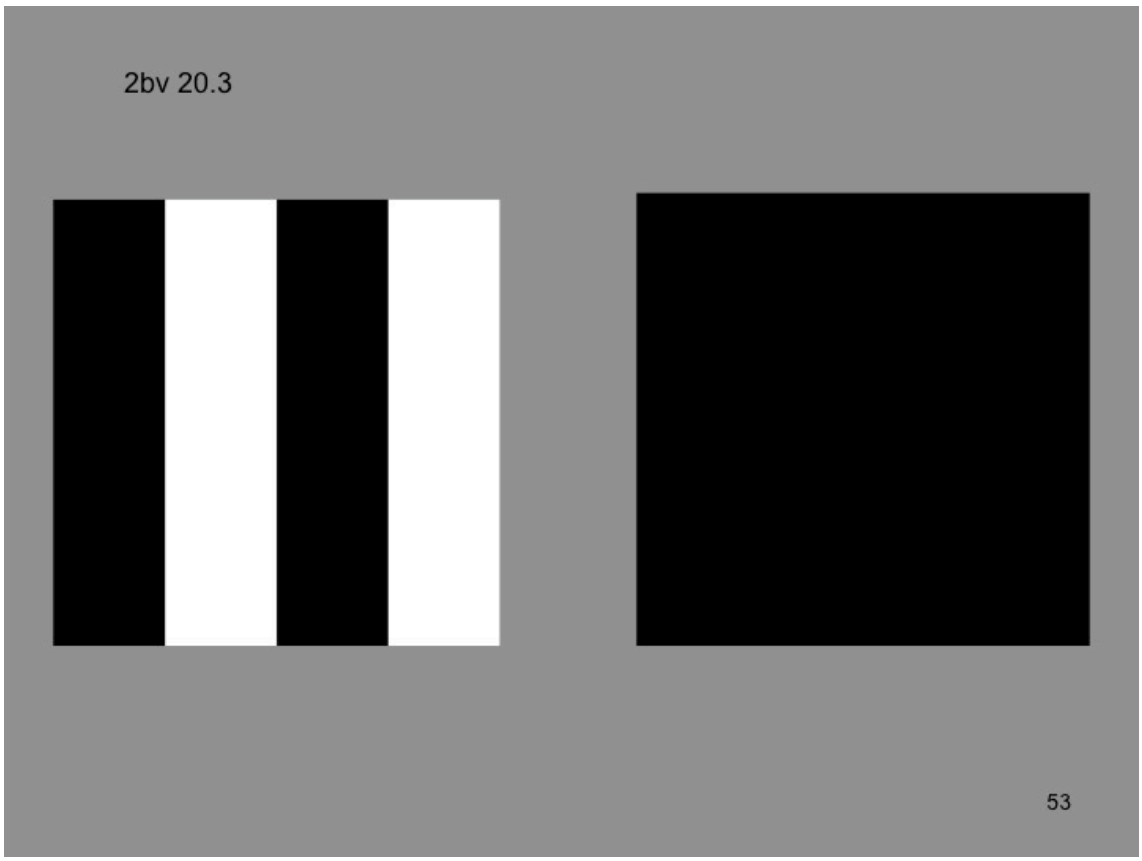
2bv 20.3
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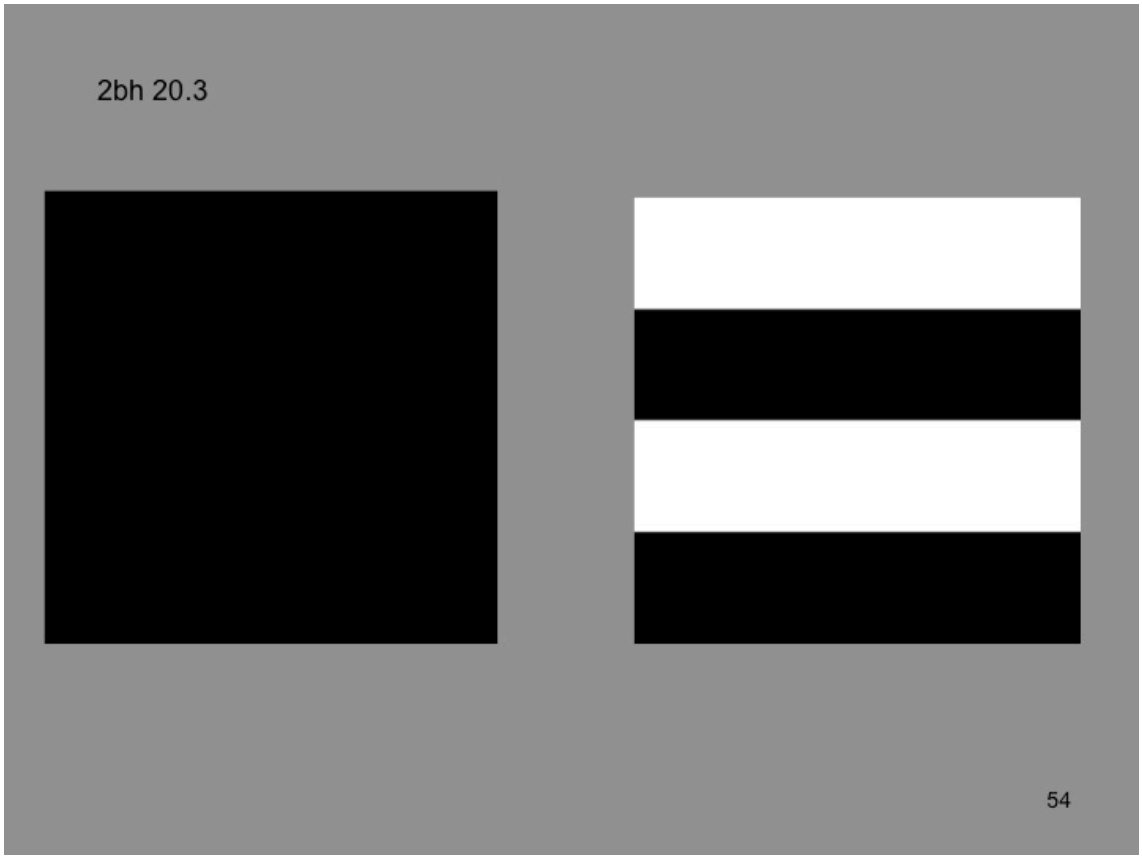
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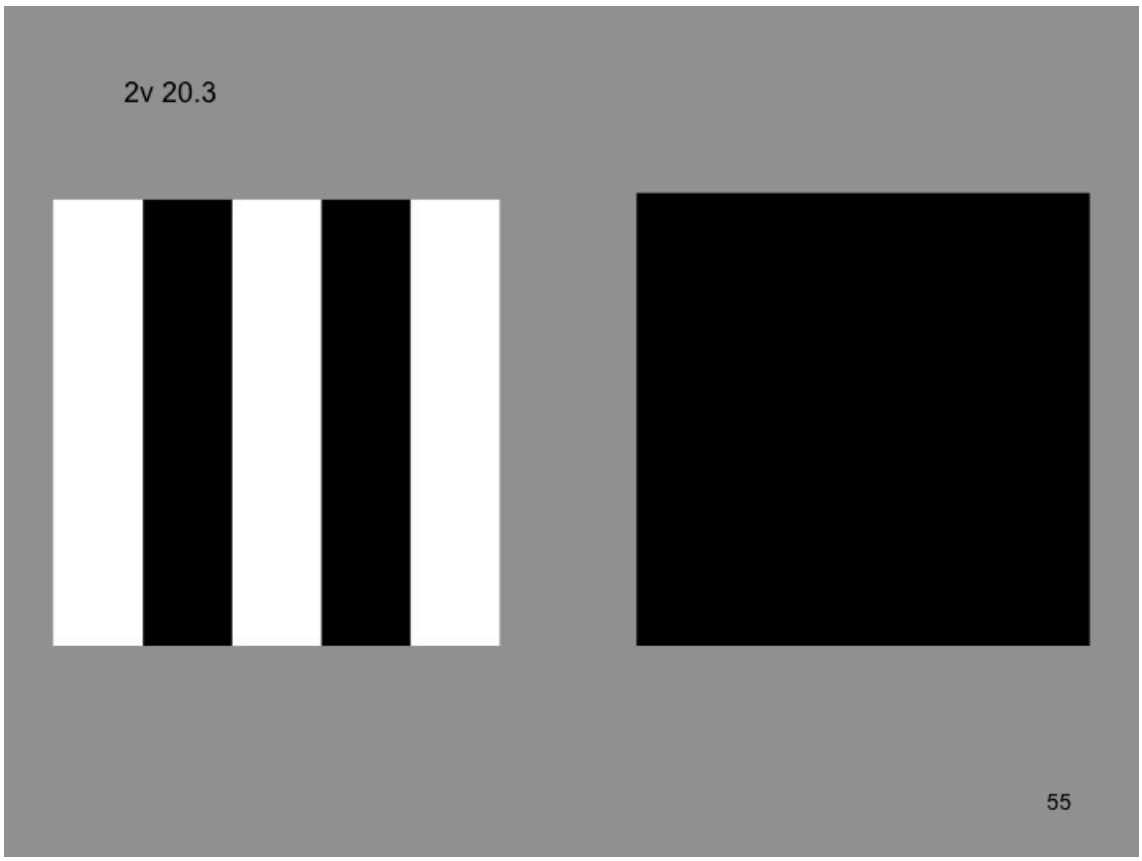
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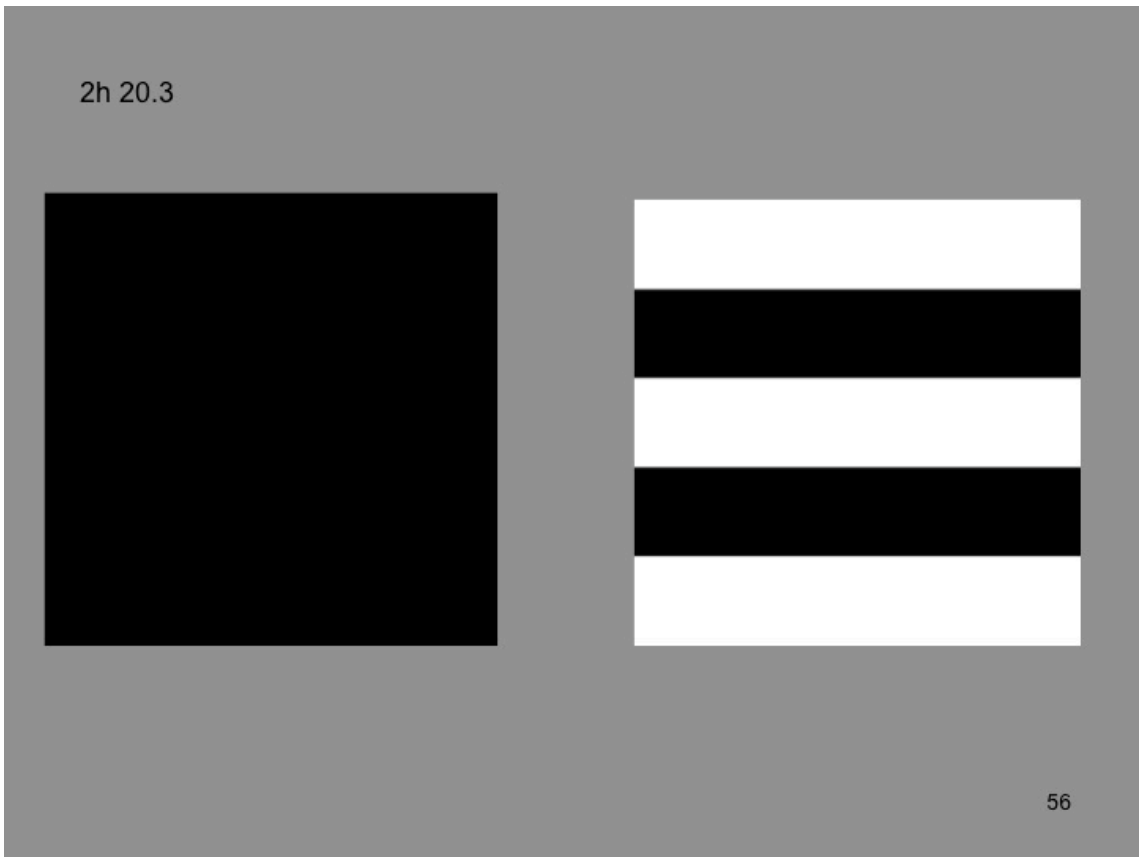
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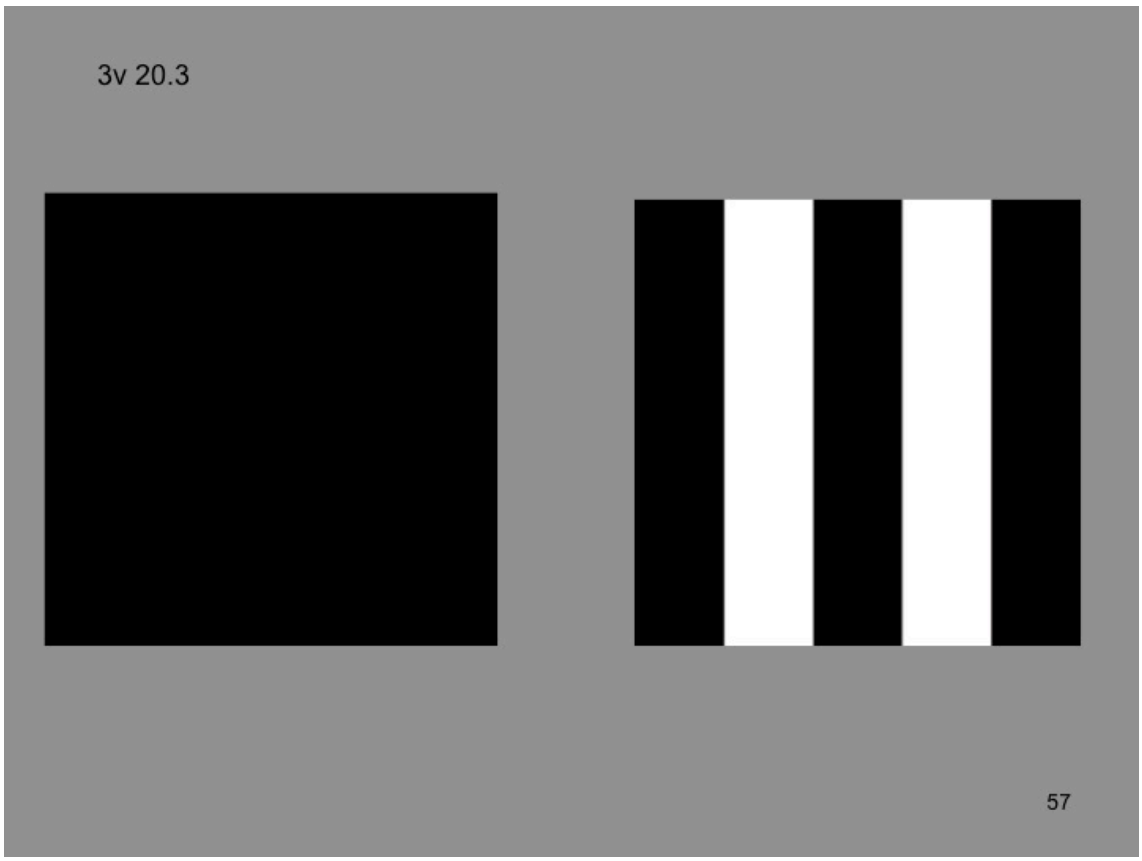
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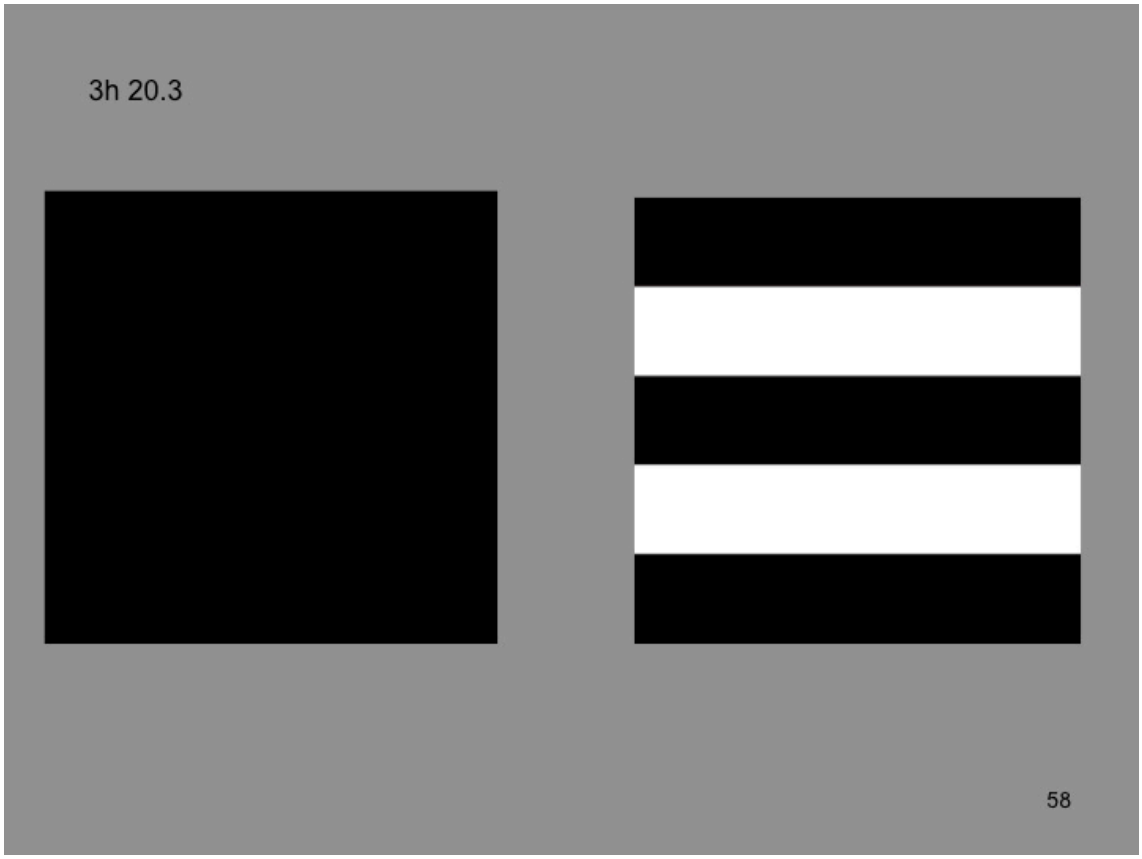
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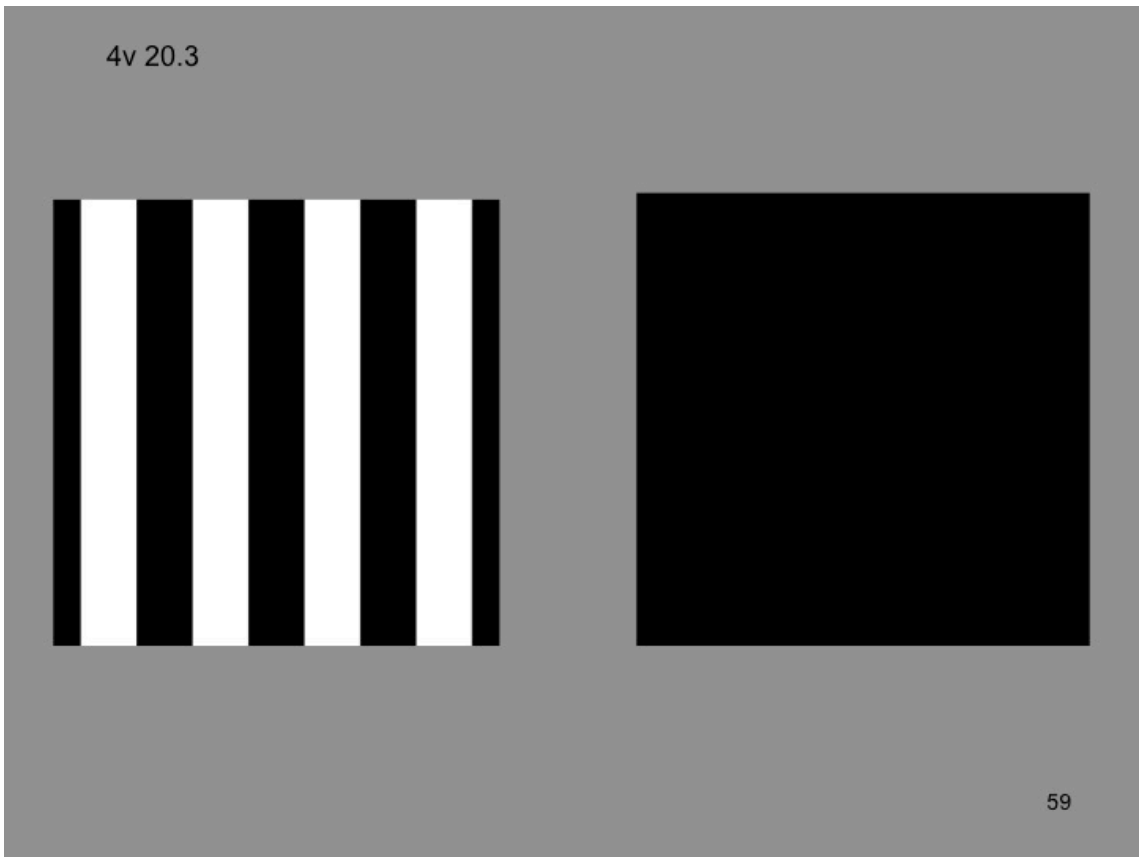
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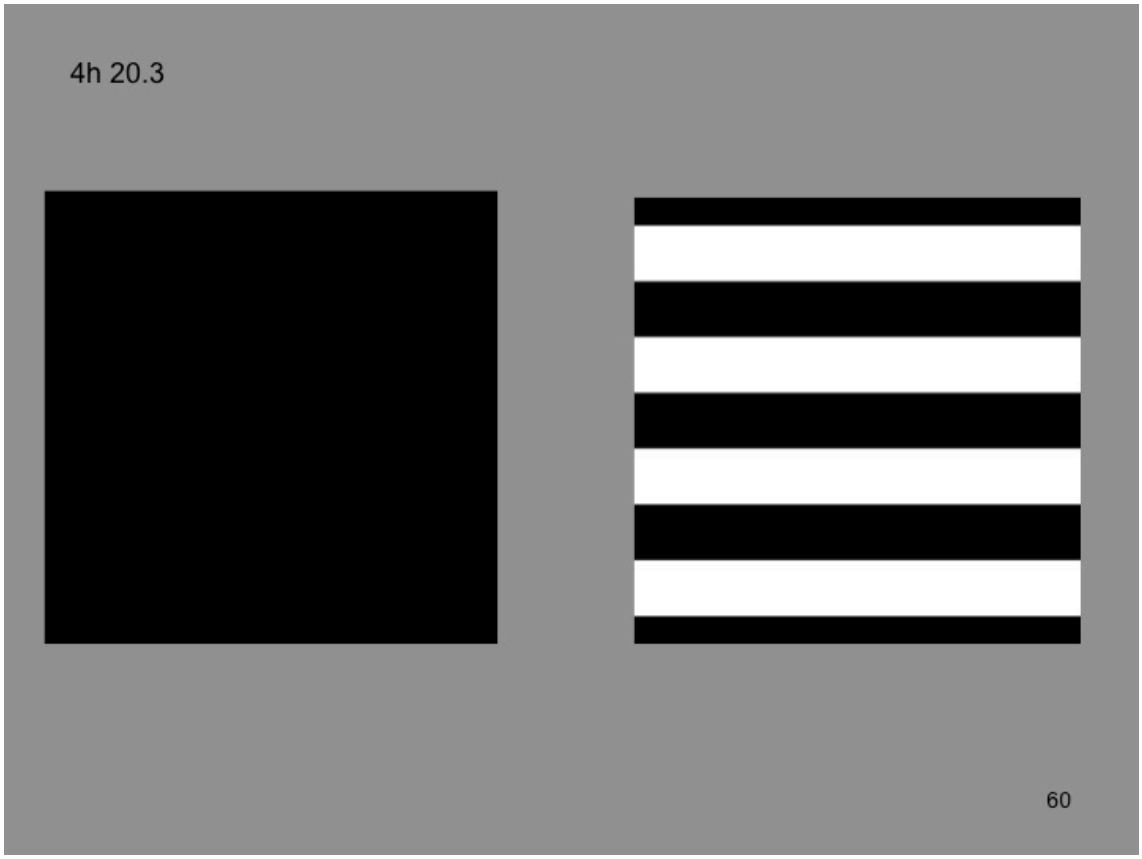
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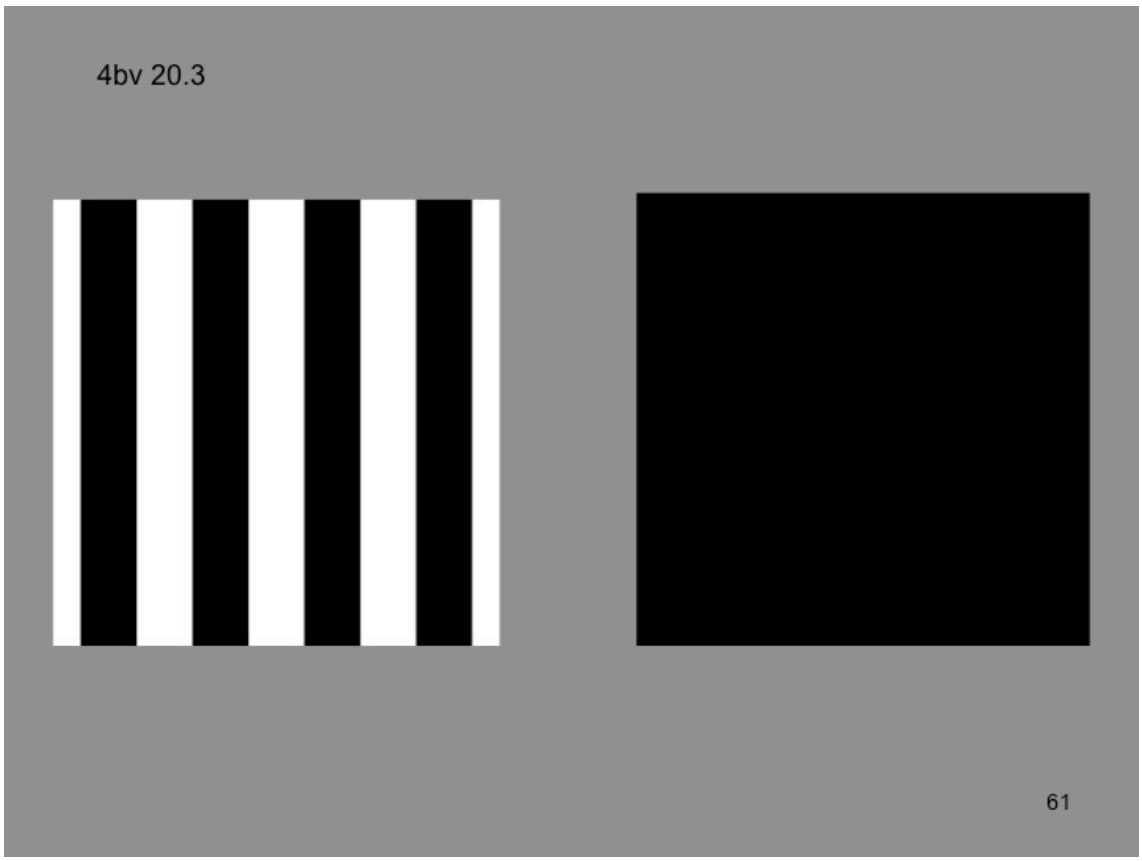
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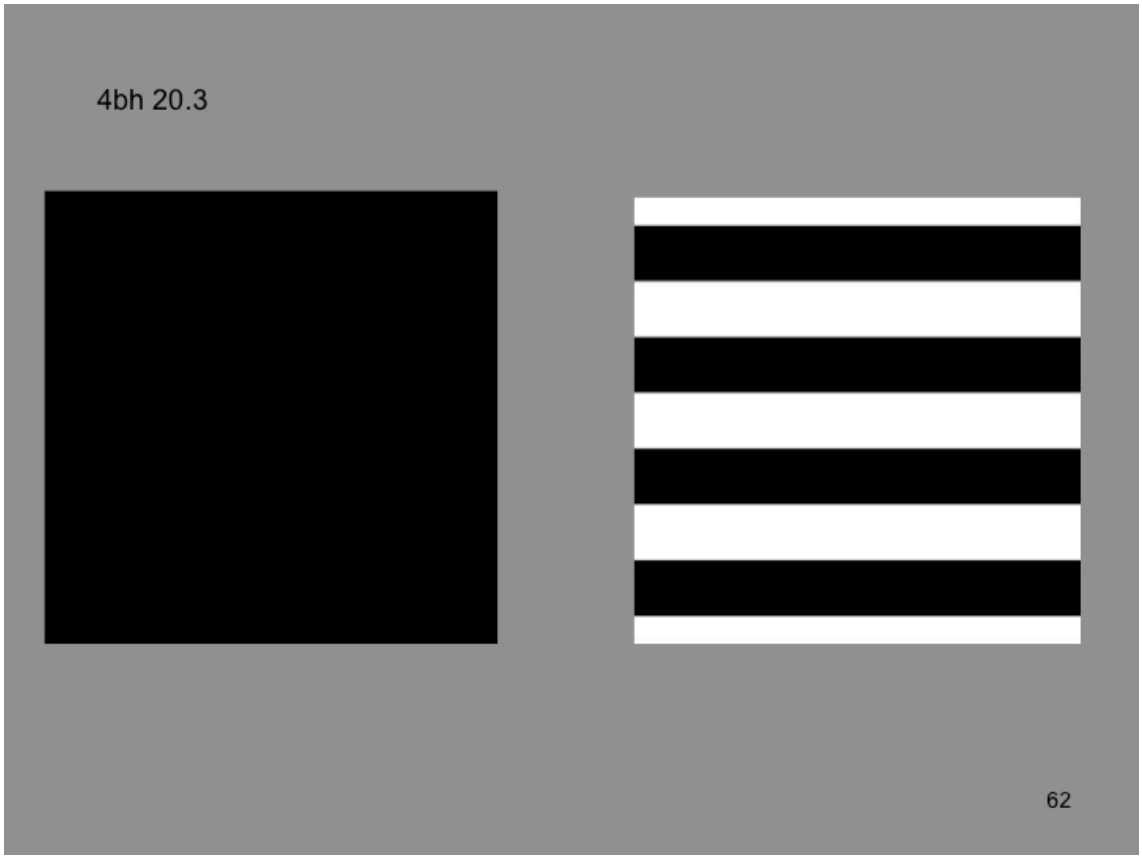
4bh 20.3
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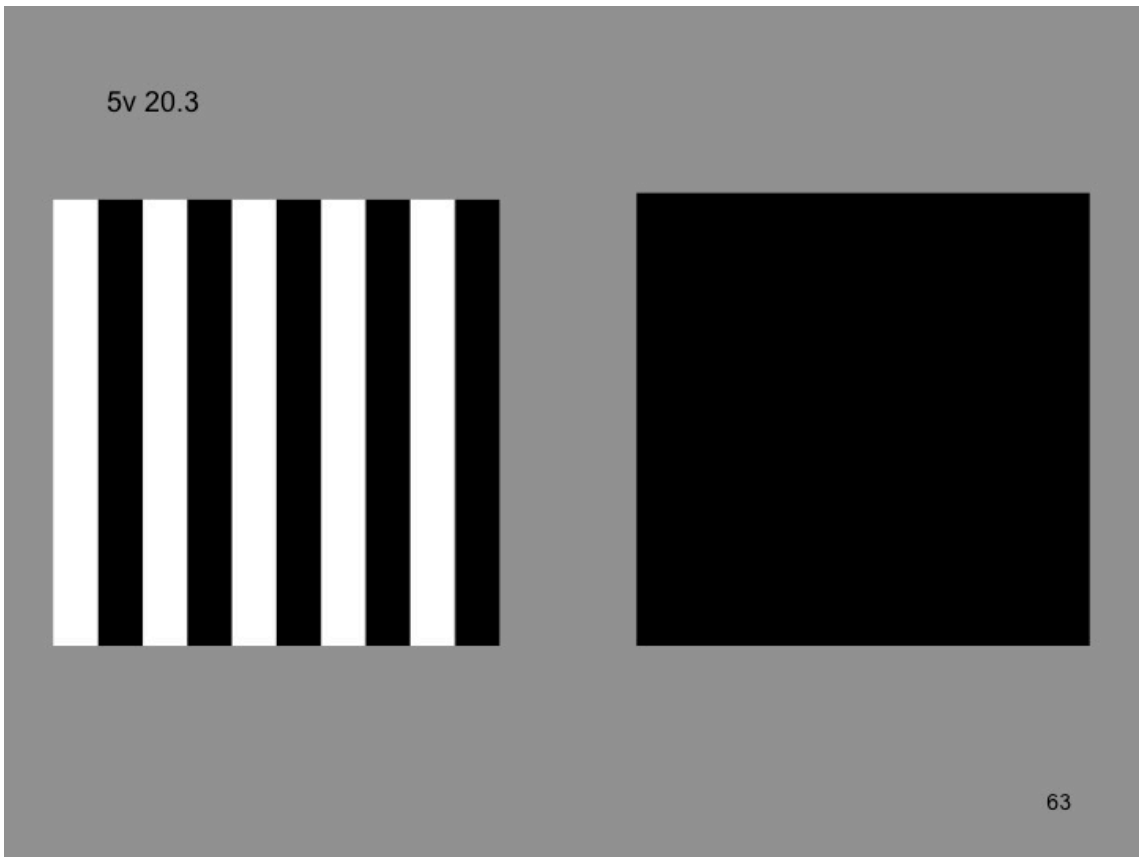
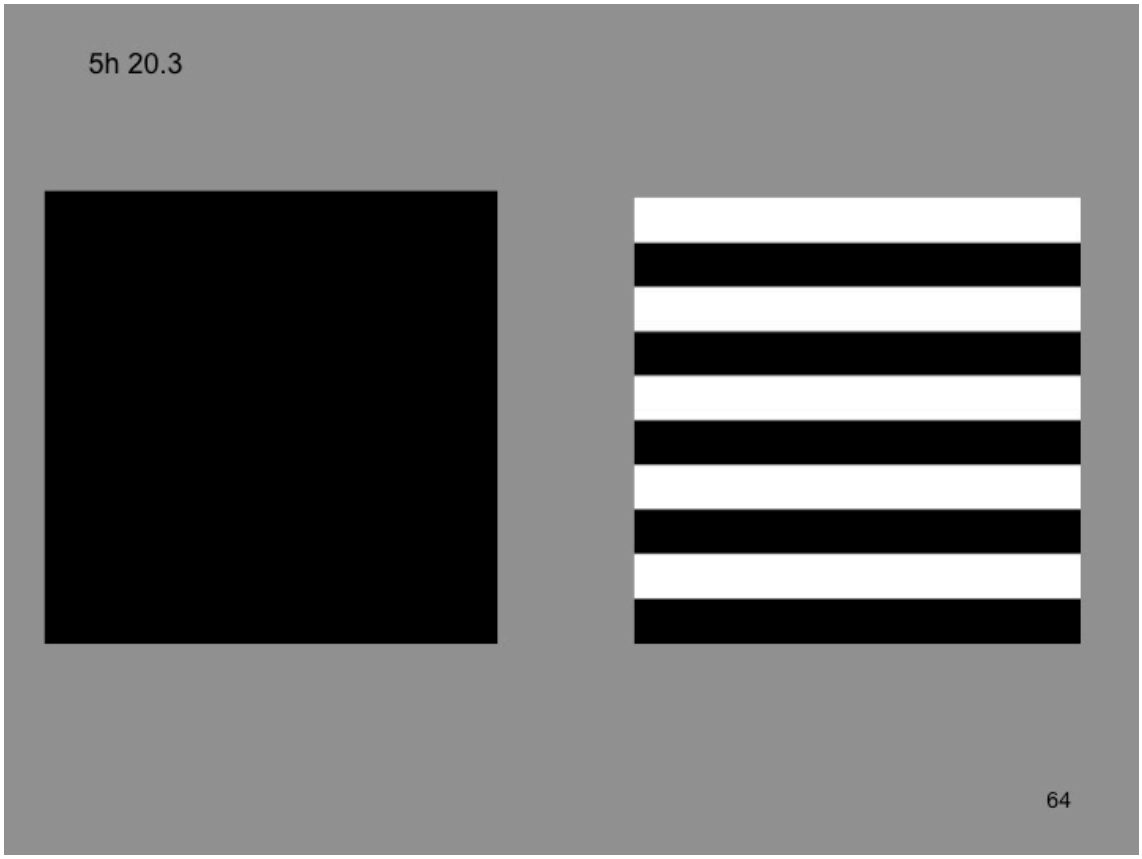

5v 20.3
63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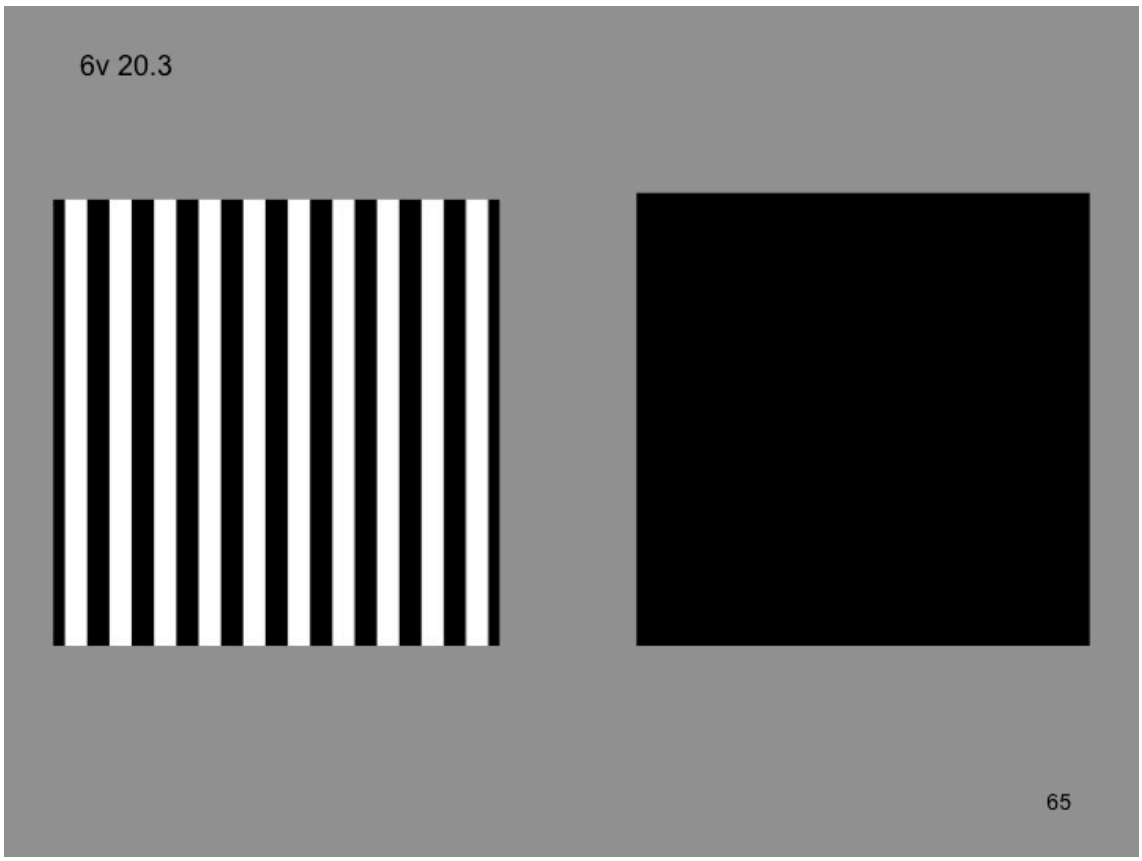
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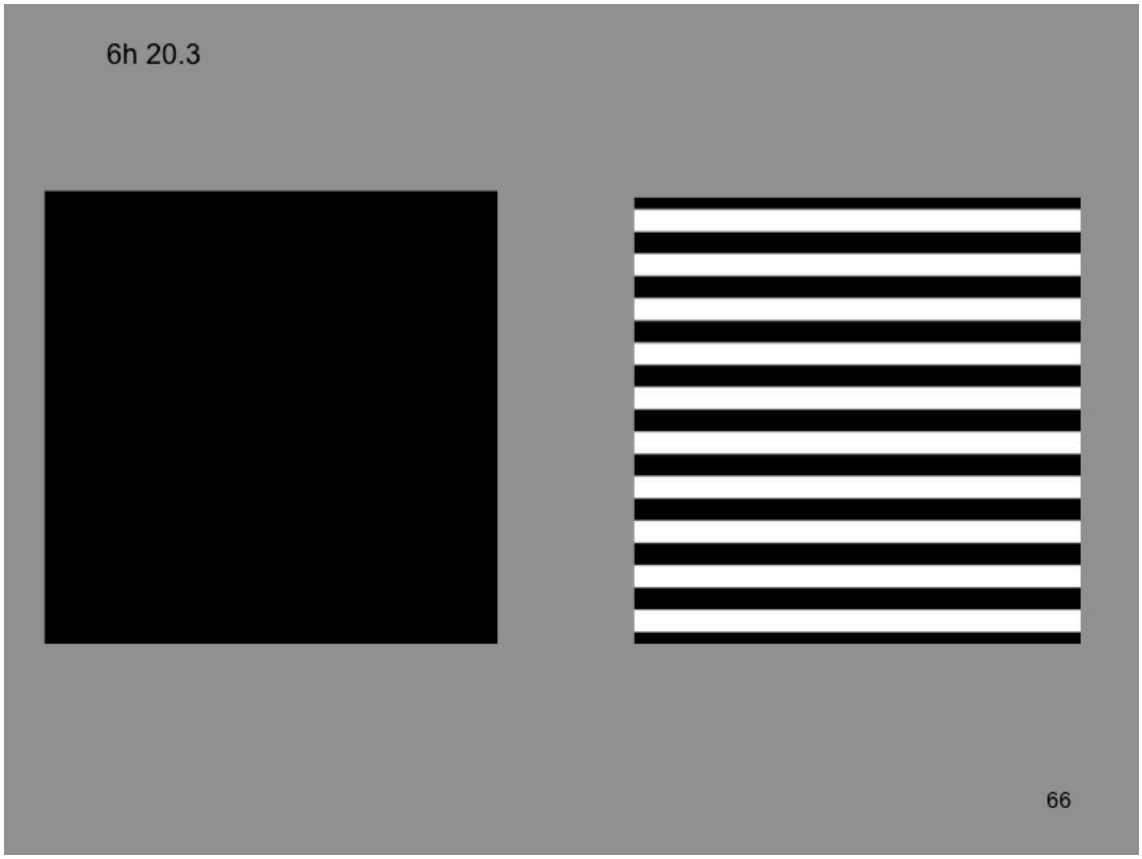
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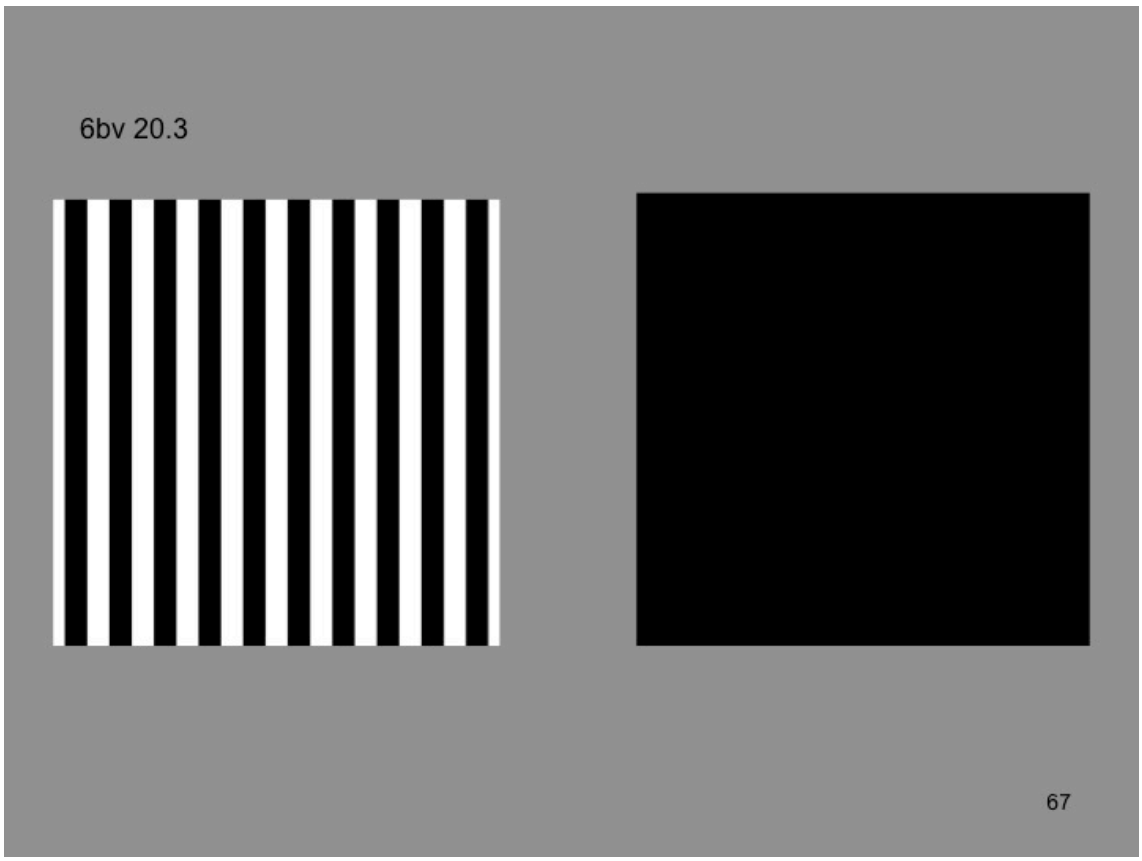
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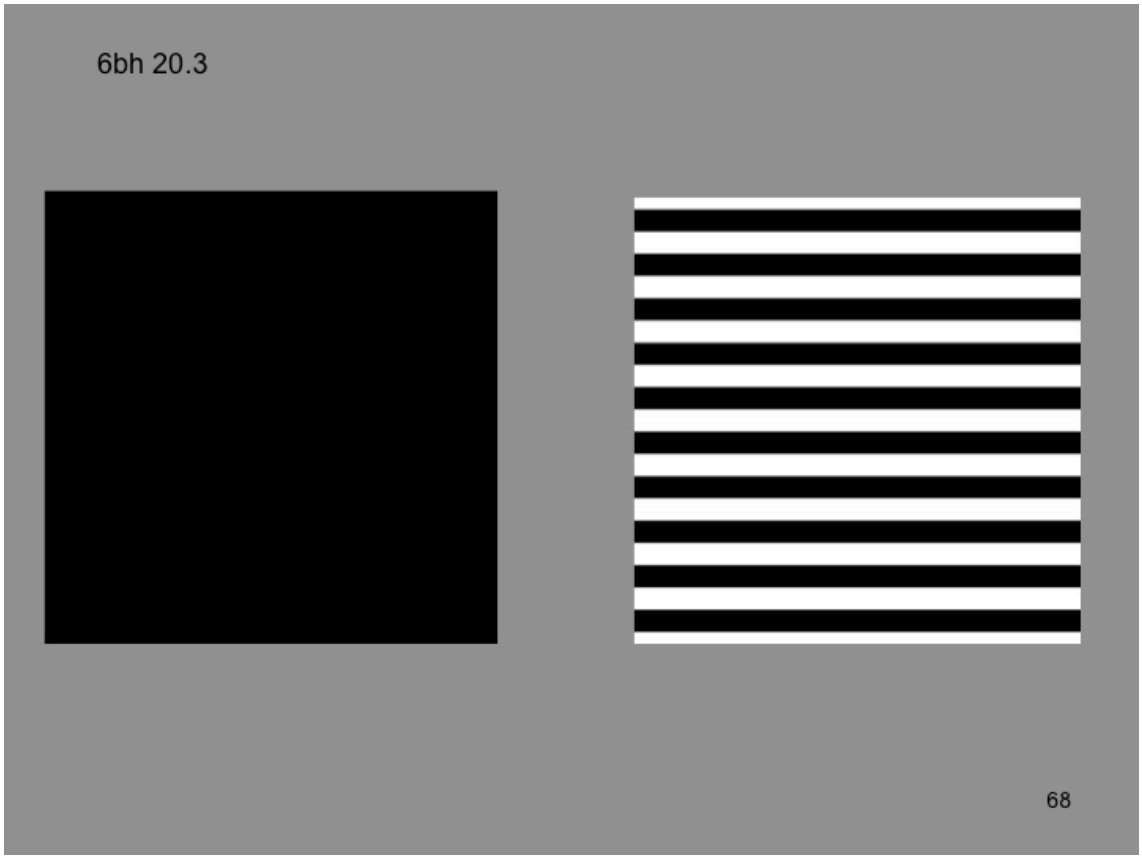
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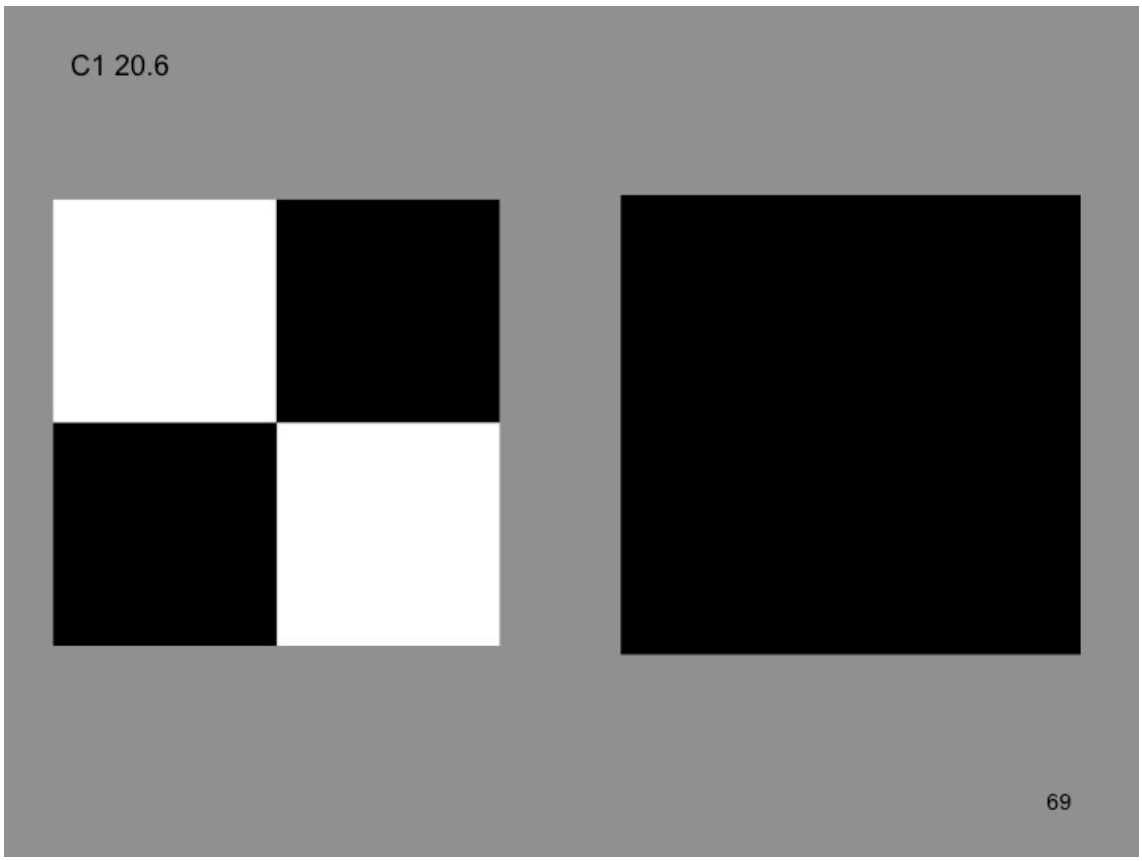
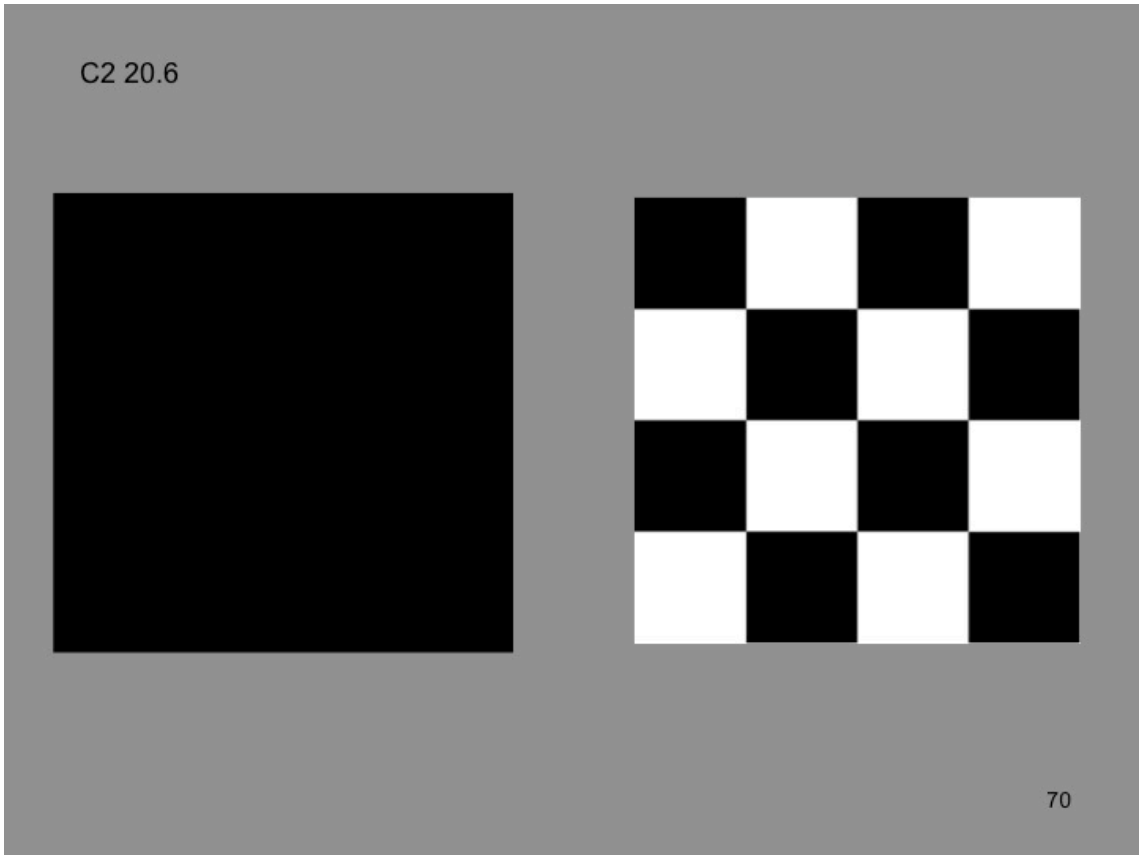
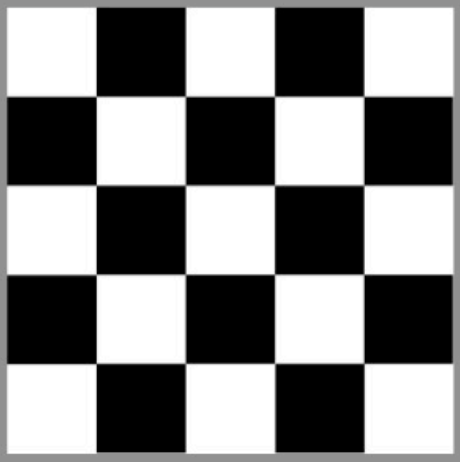
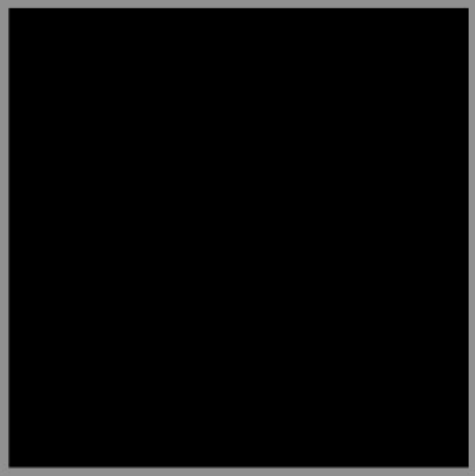

C1 20.6
69


C2 20.6
70

C3 20.6





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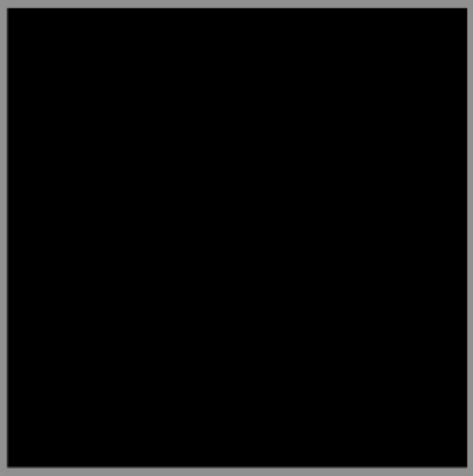
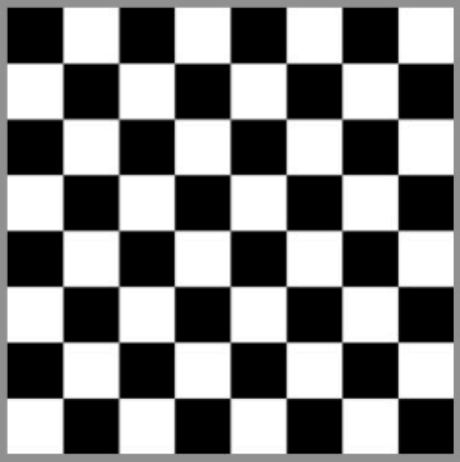
C4 20.6





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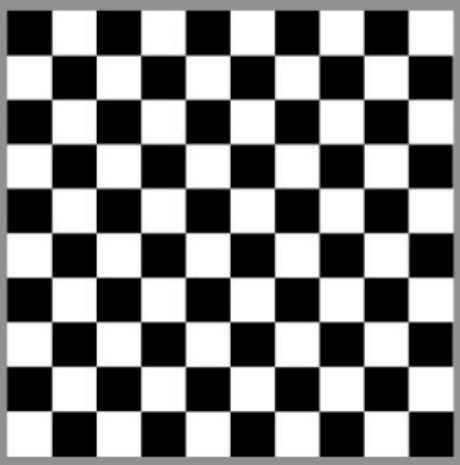

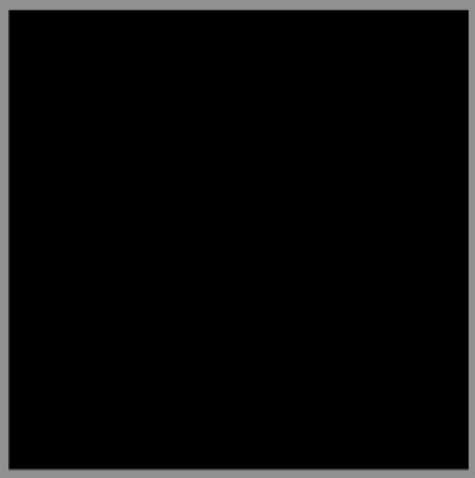

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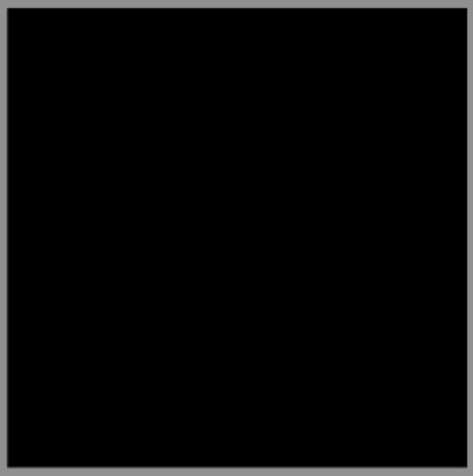
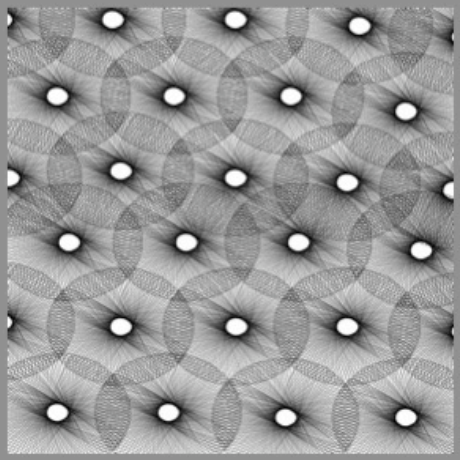
S2 20.6





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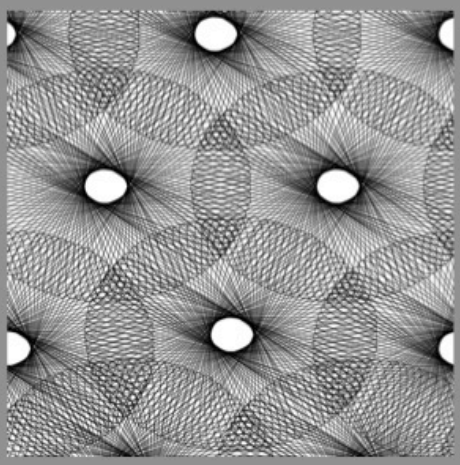
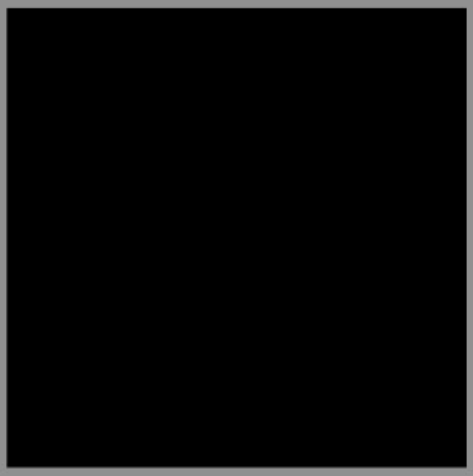
S3 20.6





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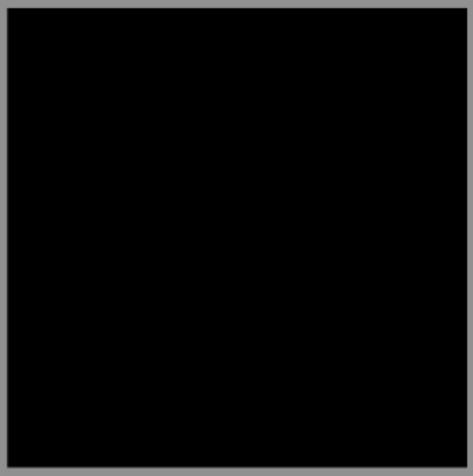

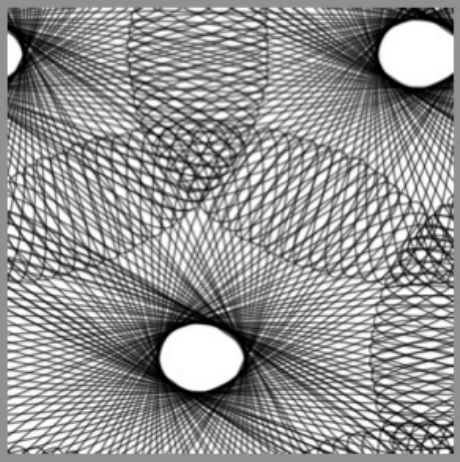

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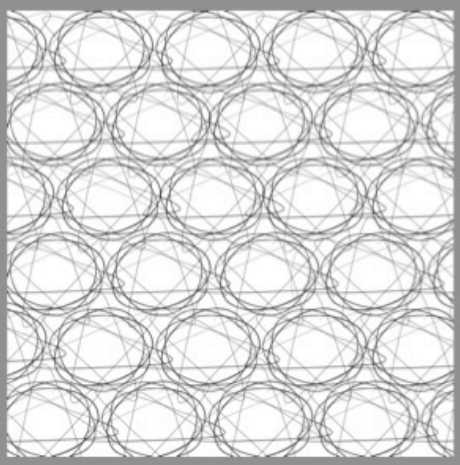

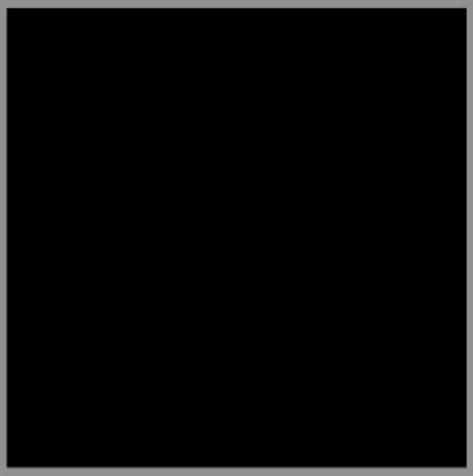

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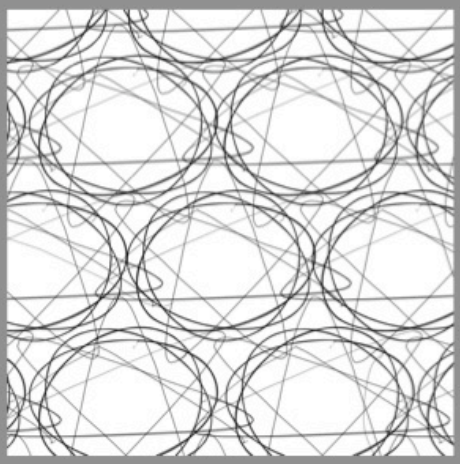
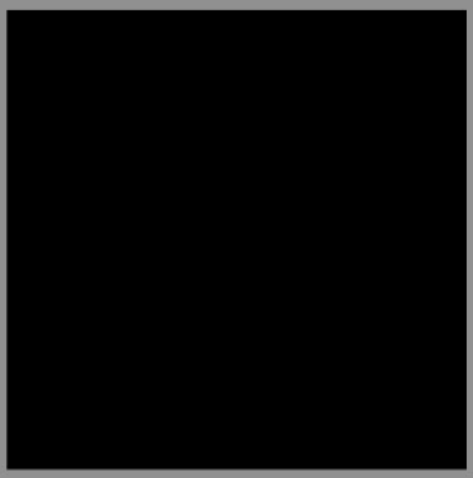
S6 20.6





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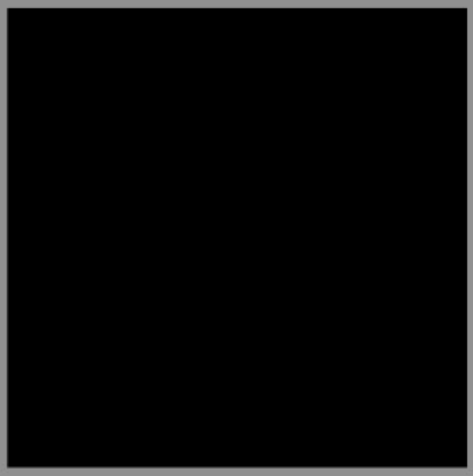

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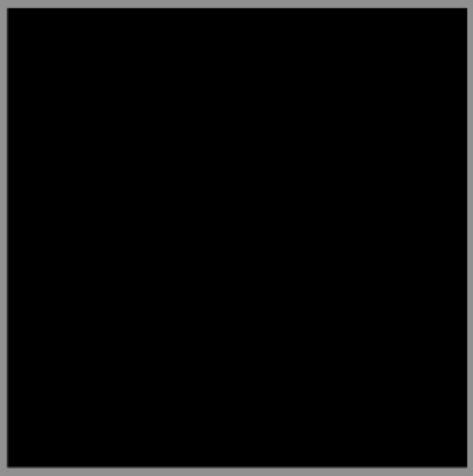

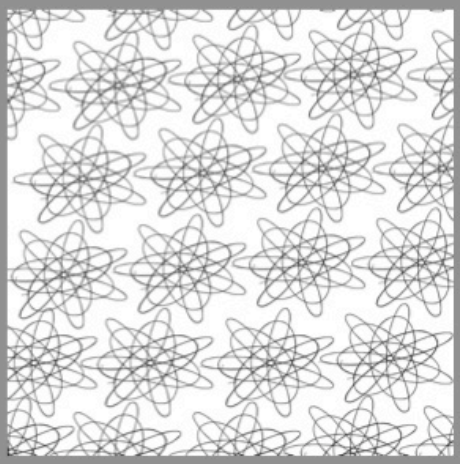

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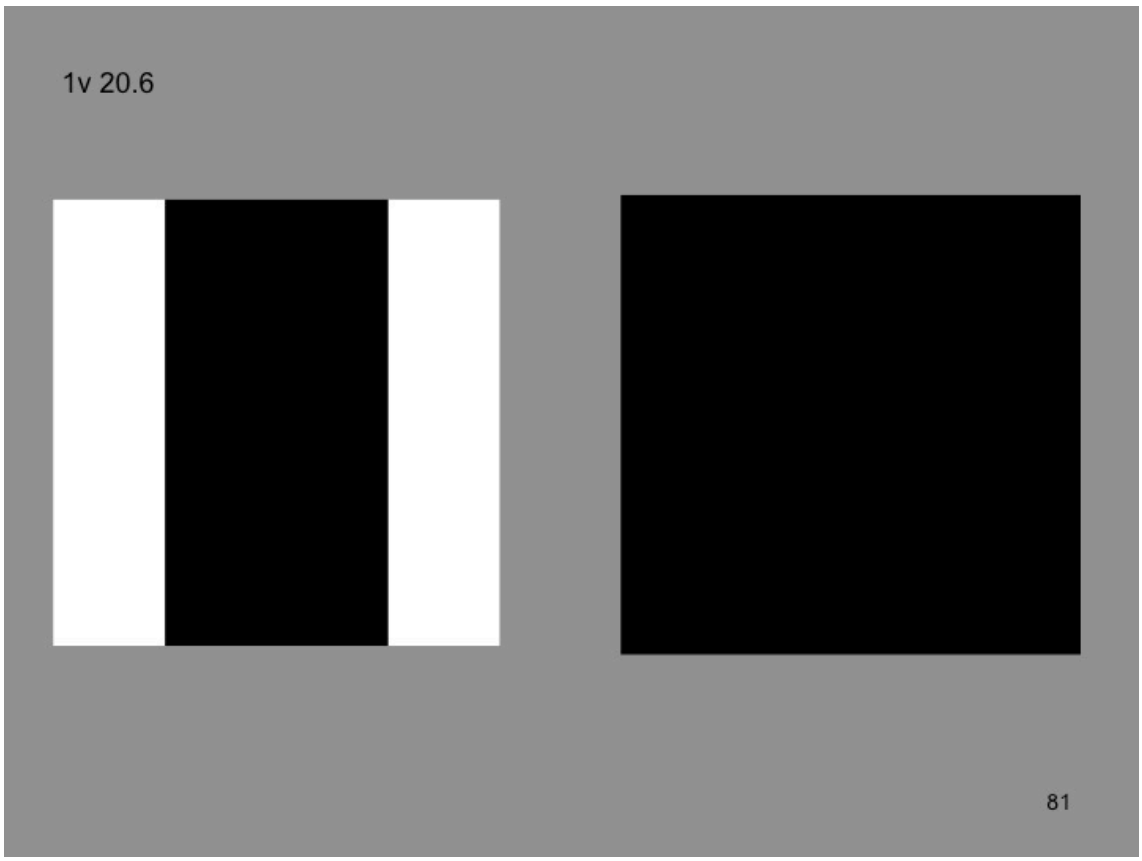
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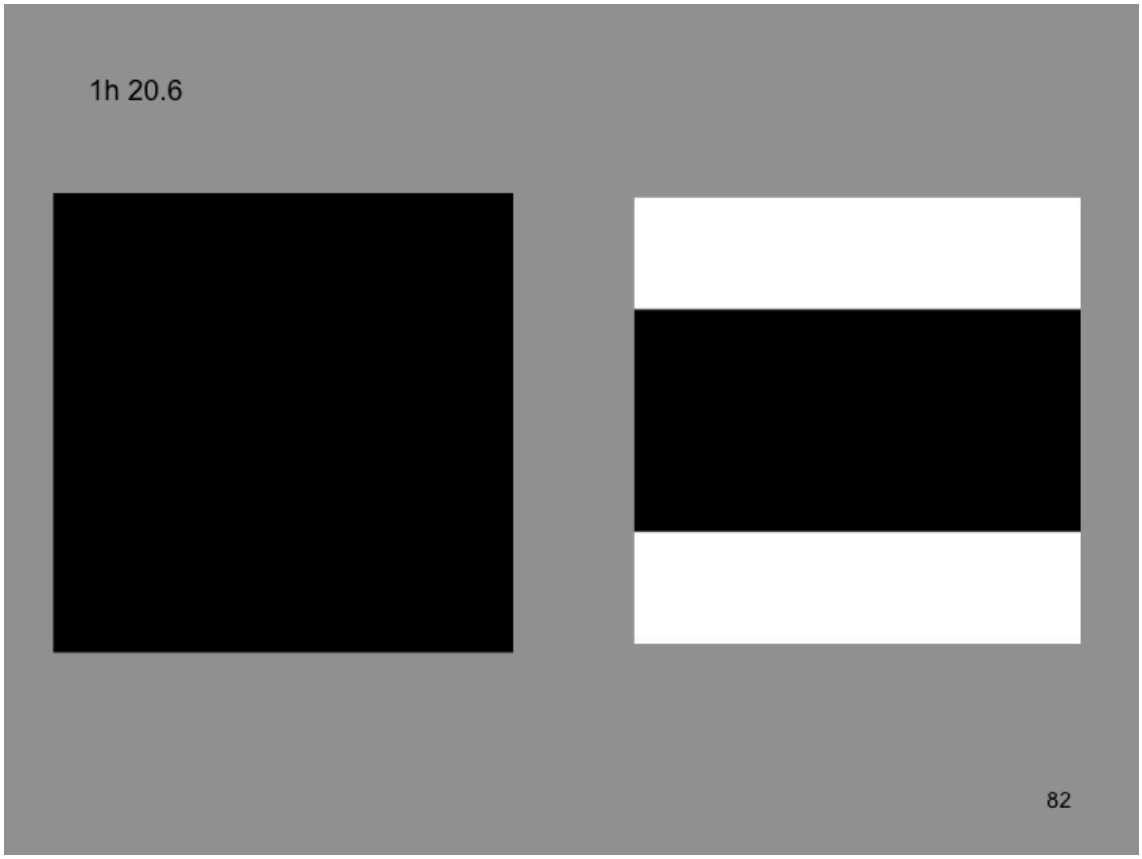
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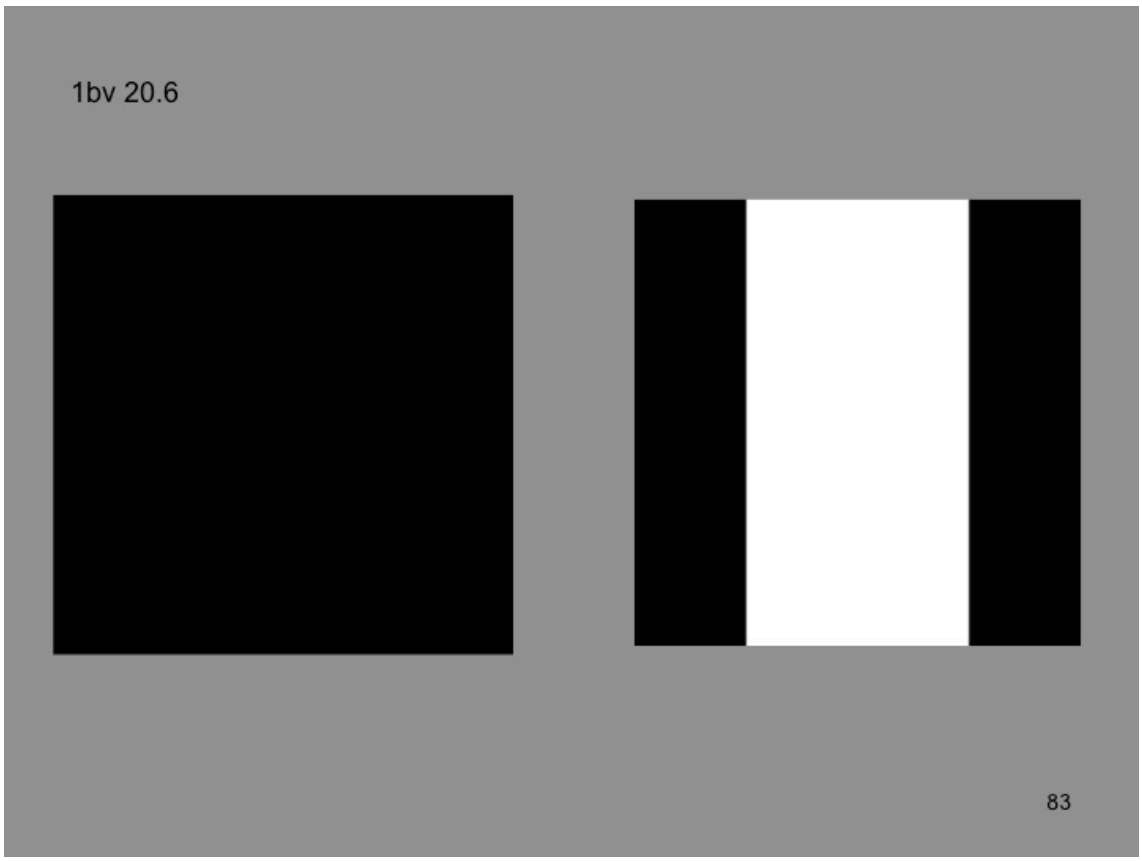
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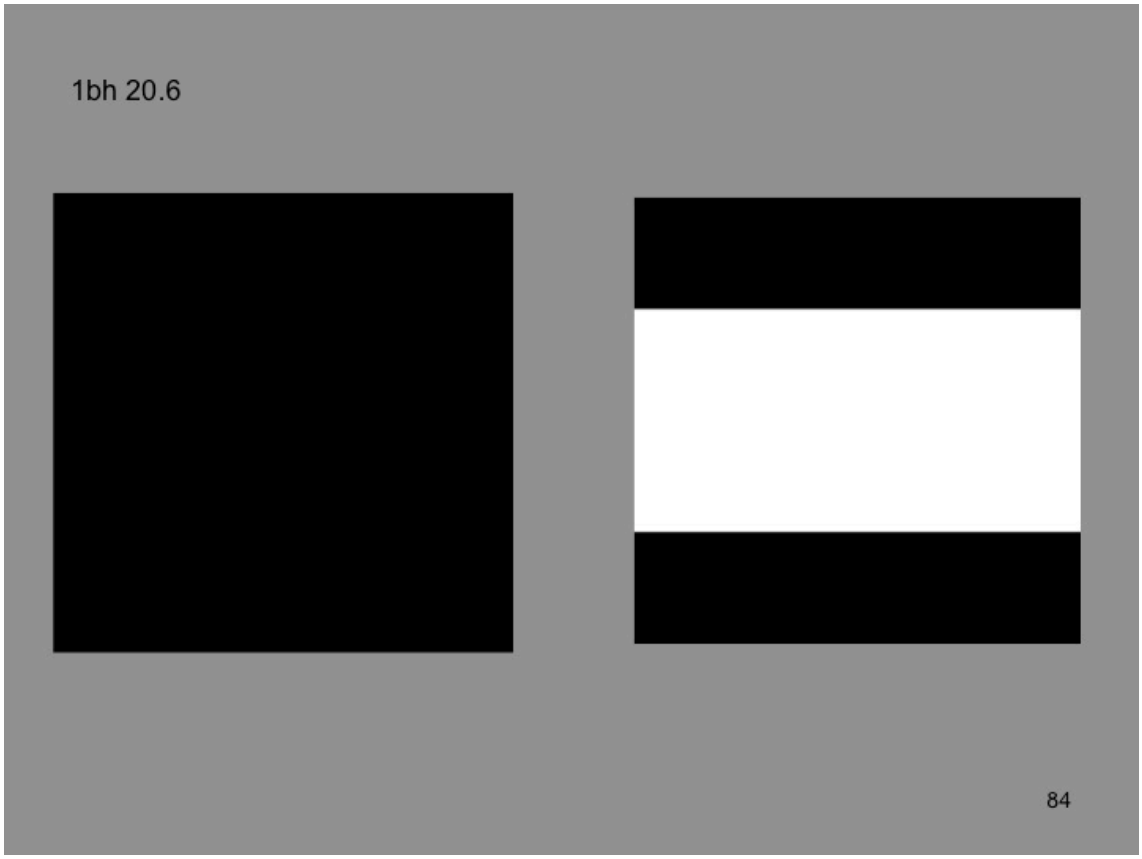
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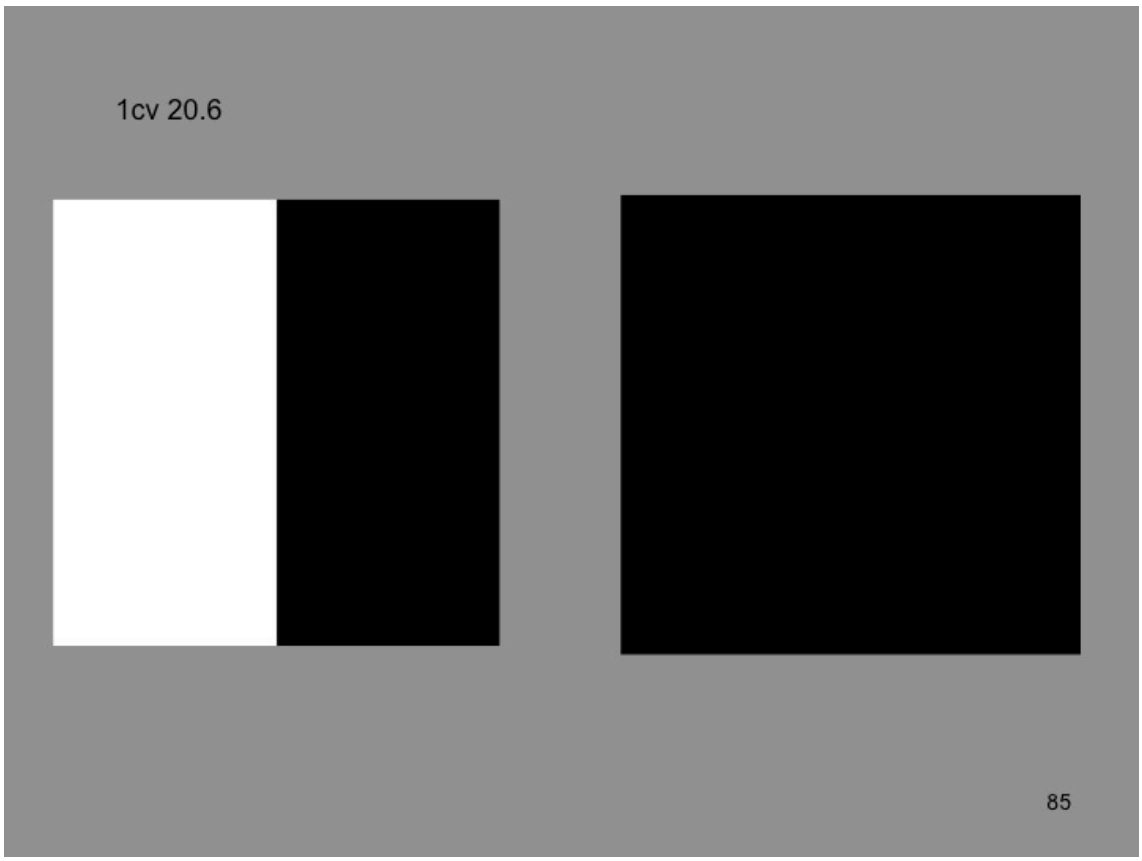
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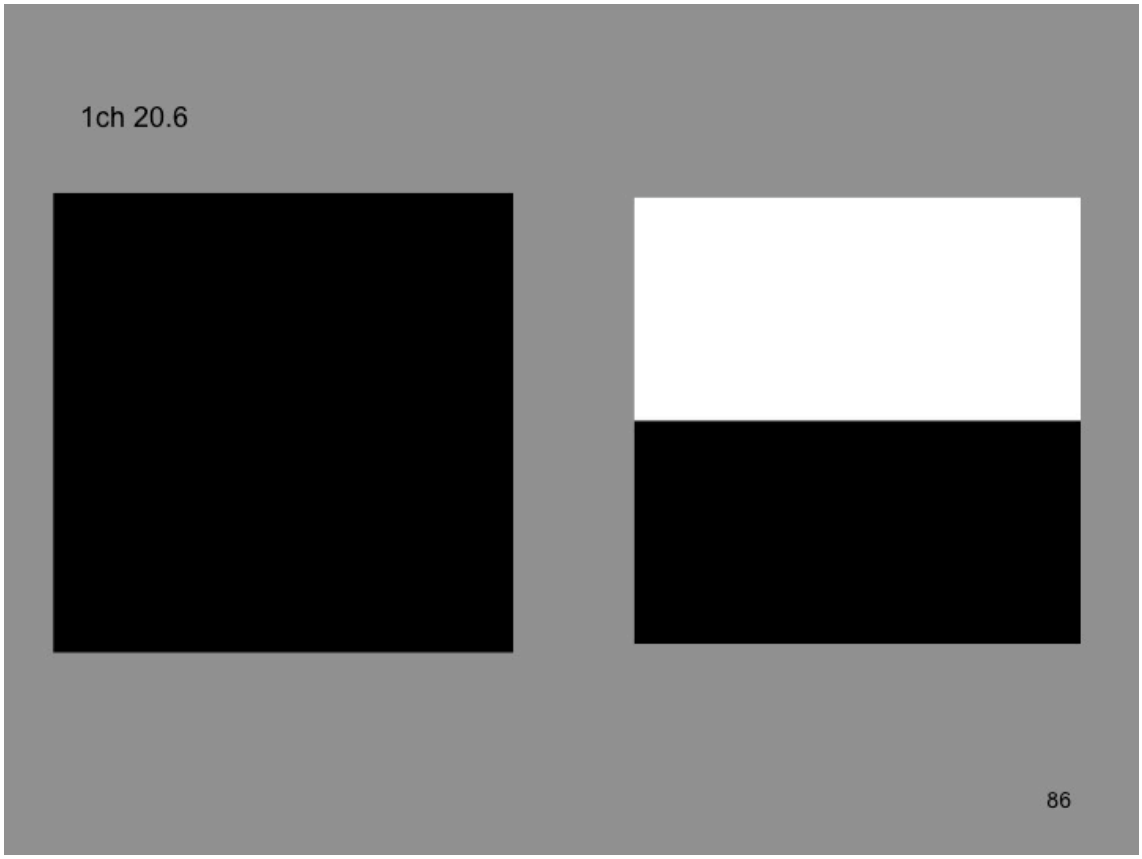
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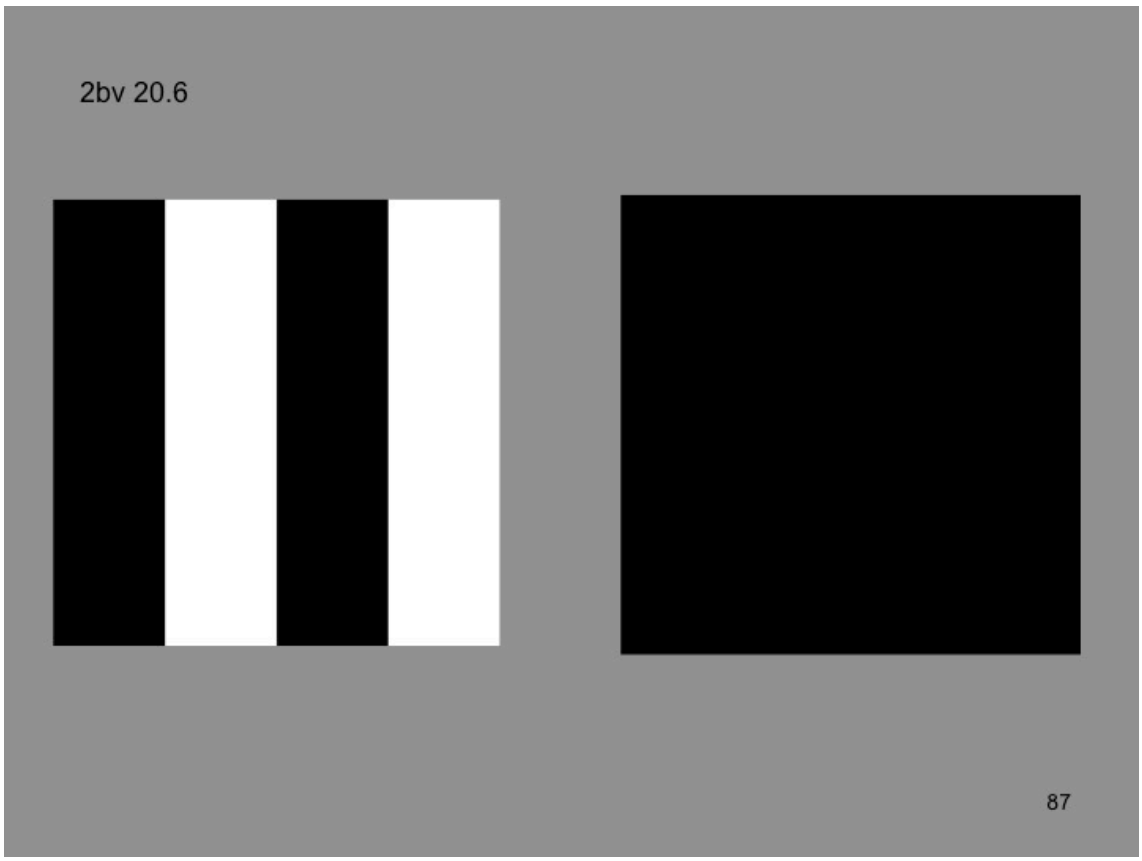
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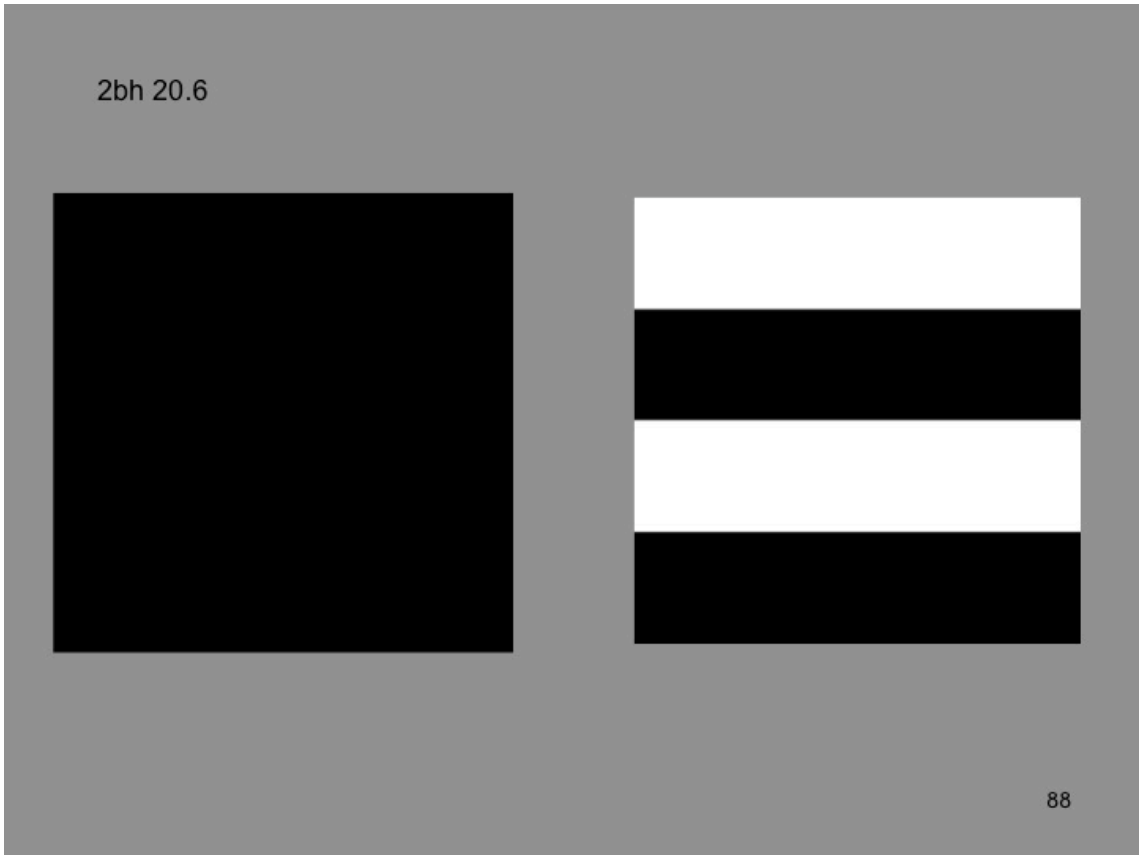
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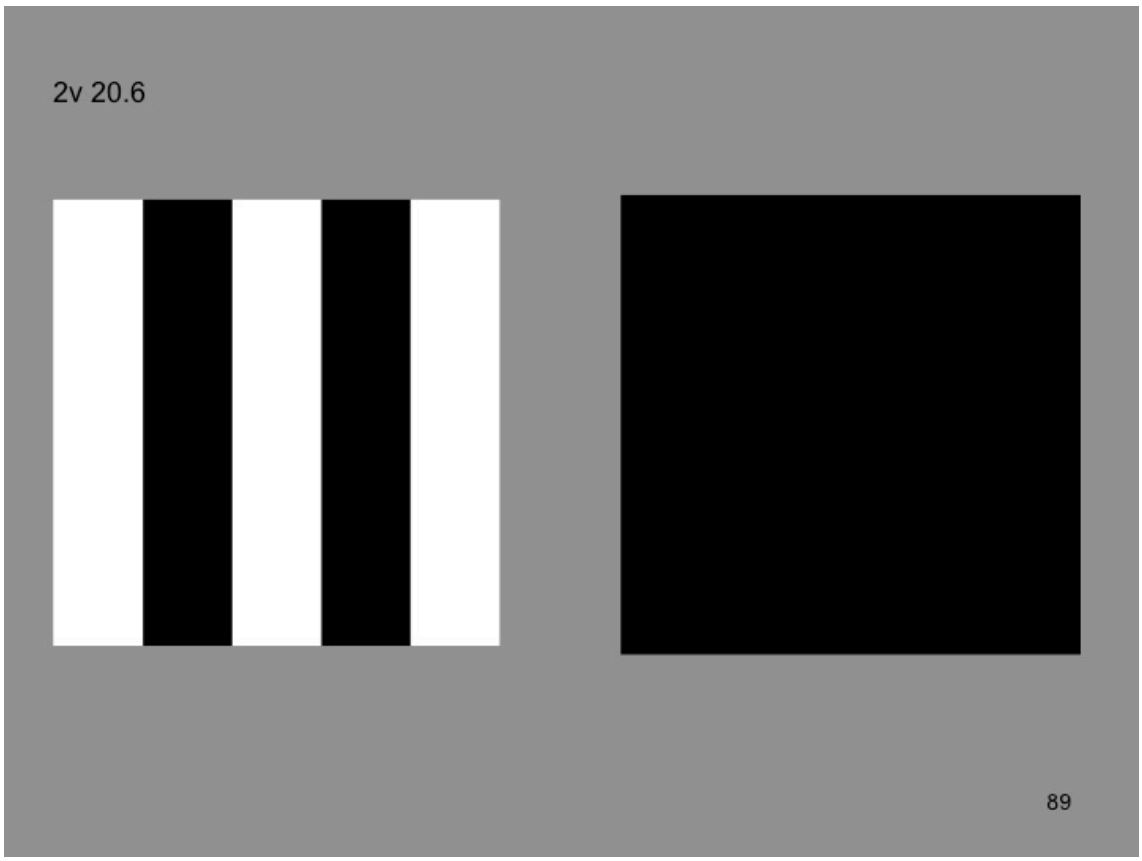
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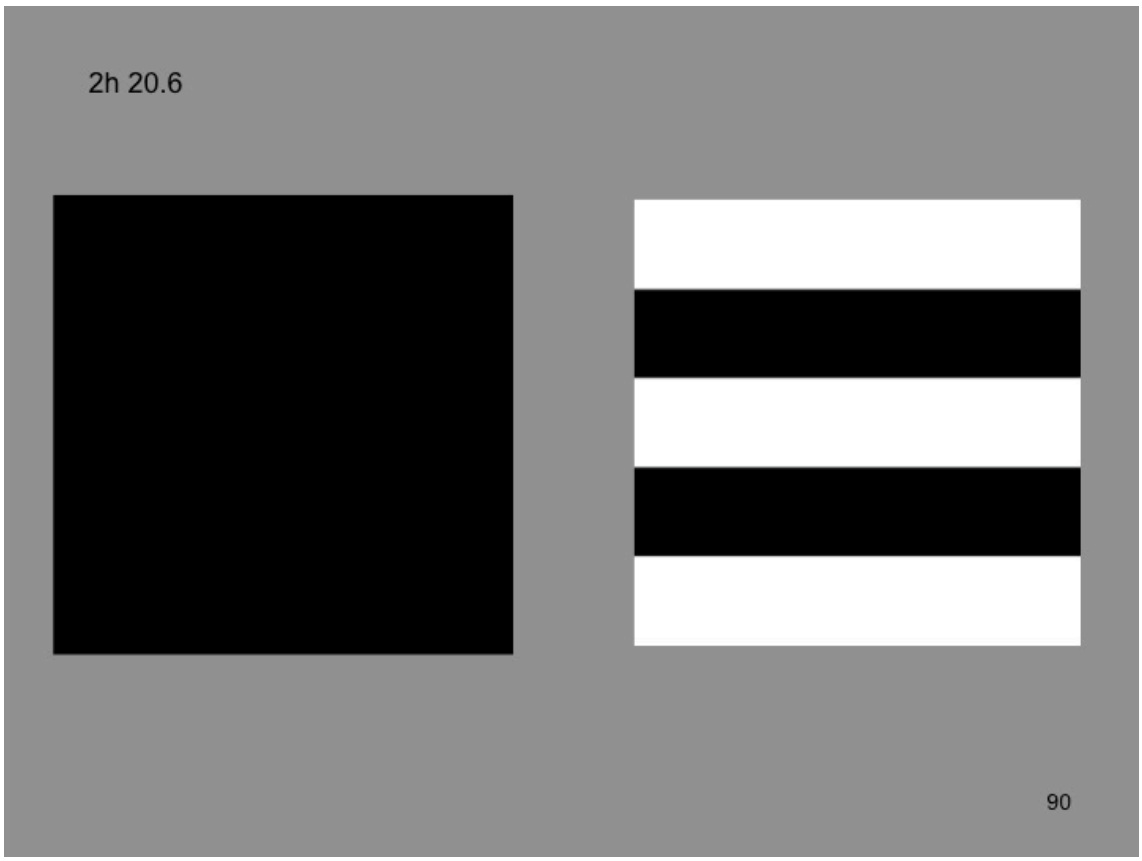
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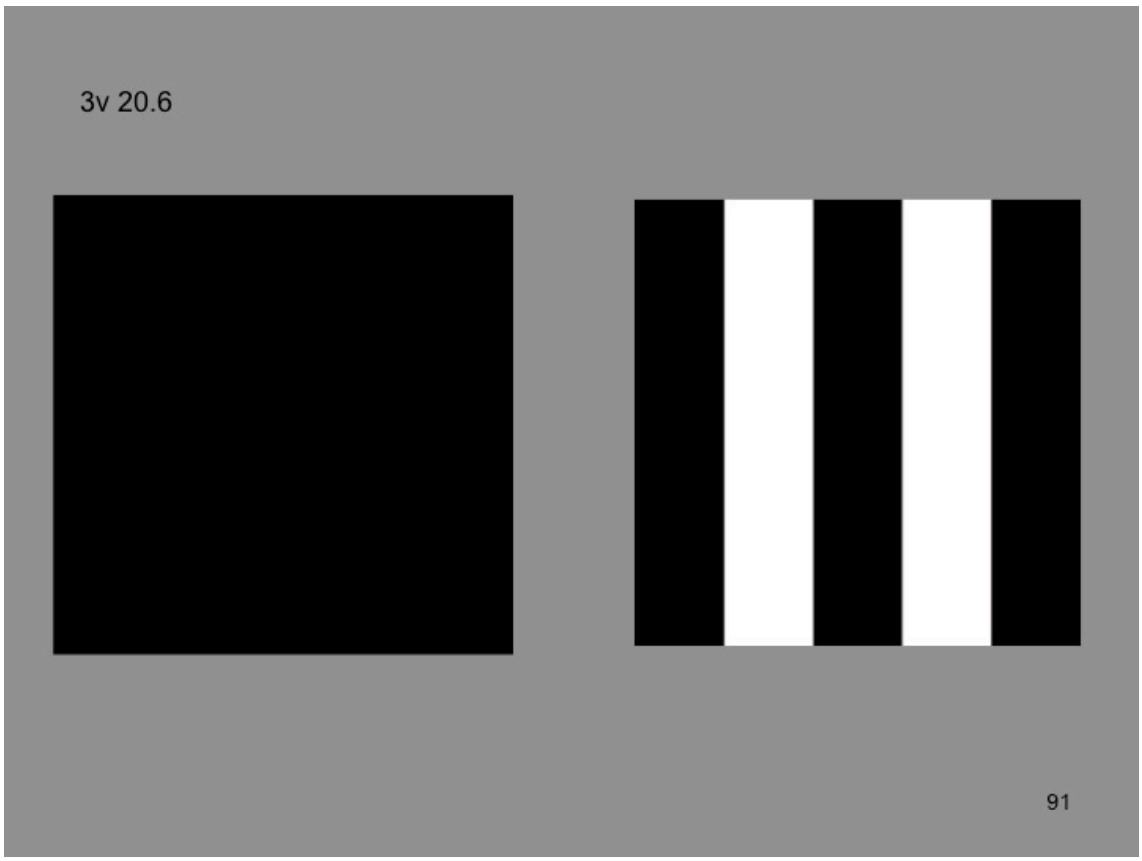
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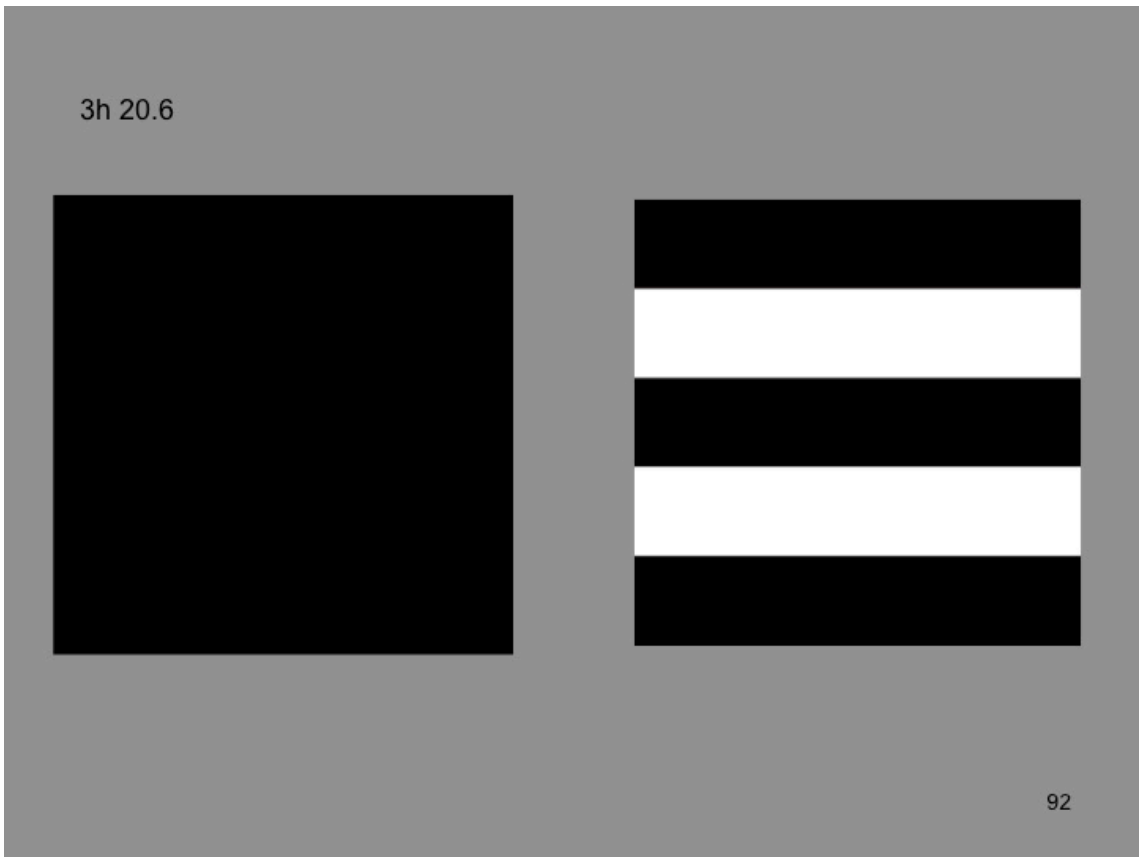
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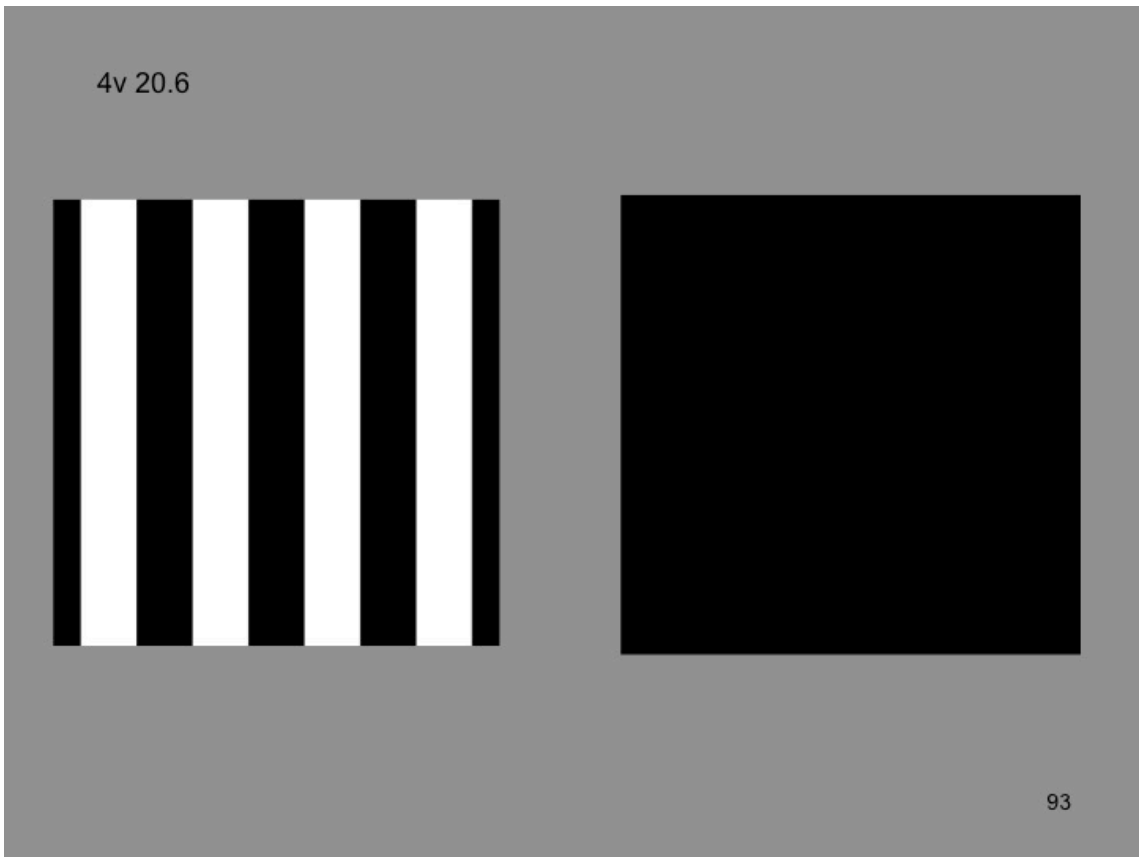
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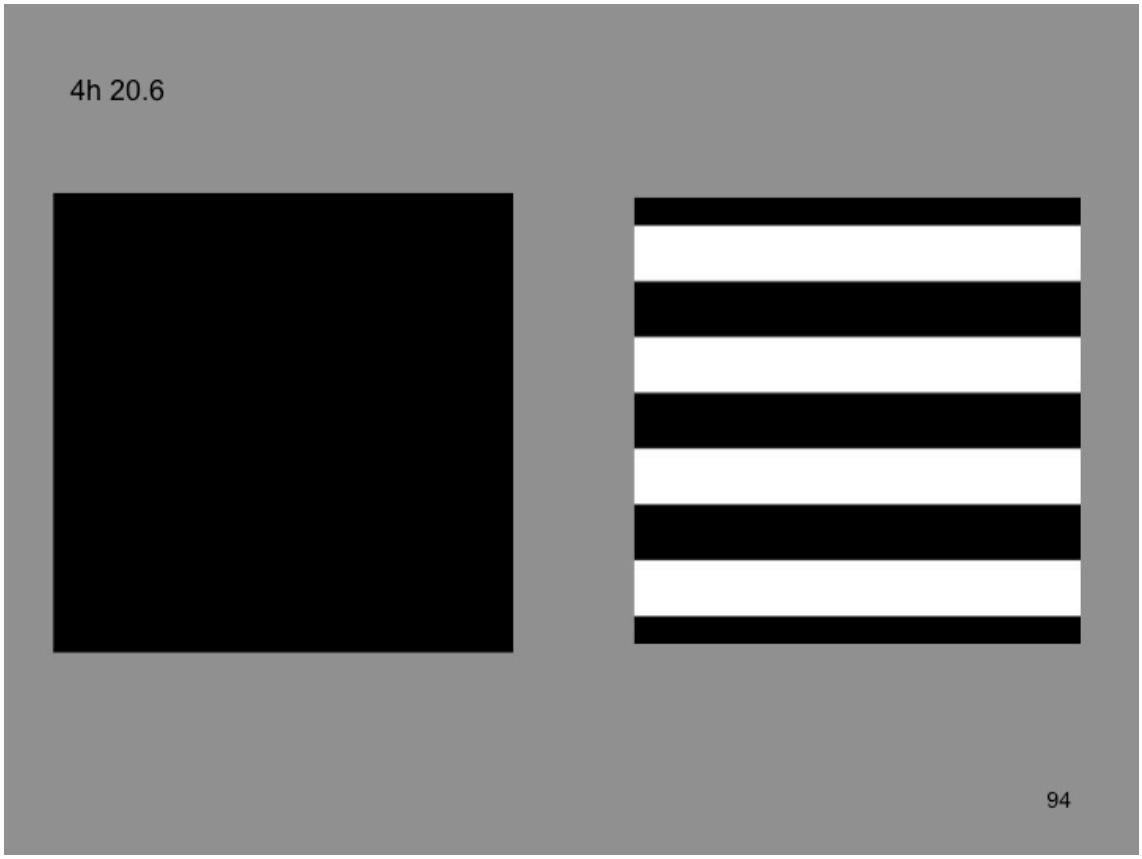
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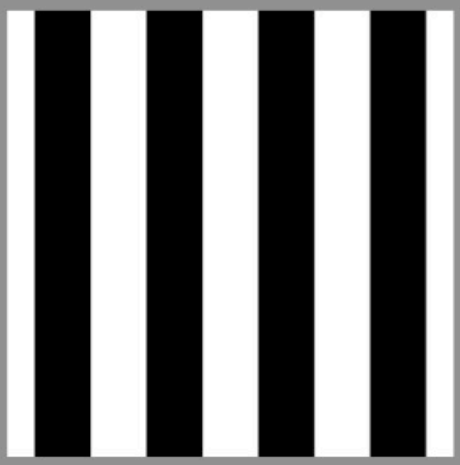
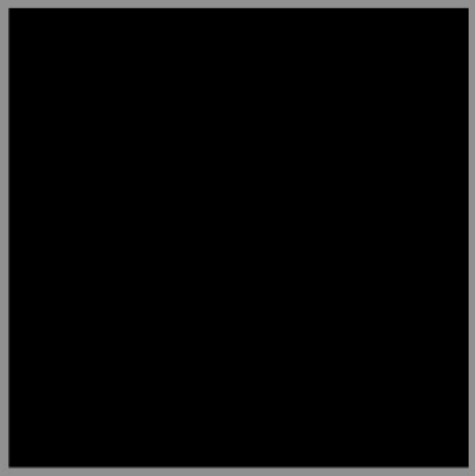
4bv 20.6





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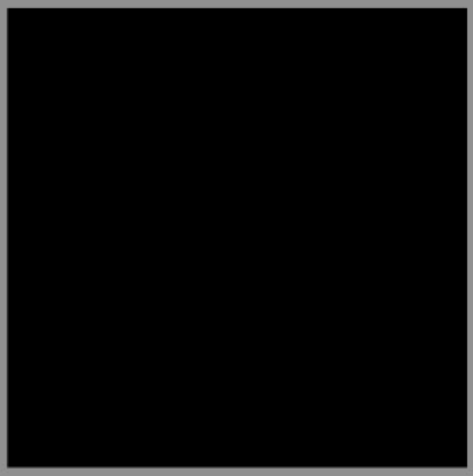

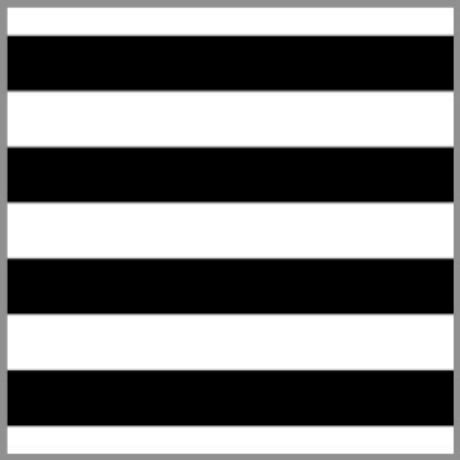

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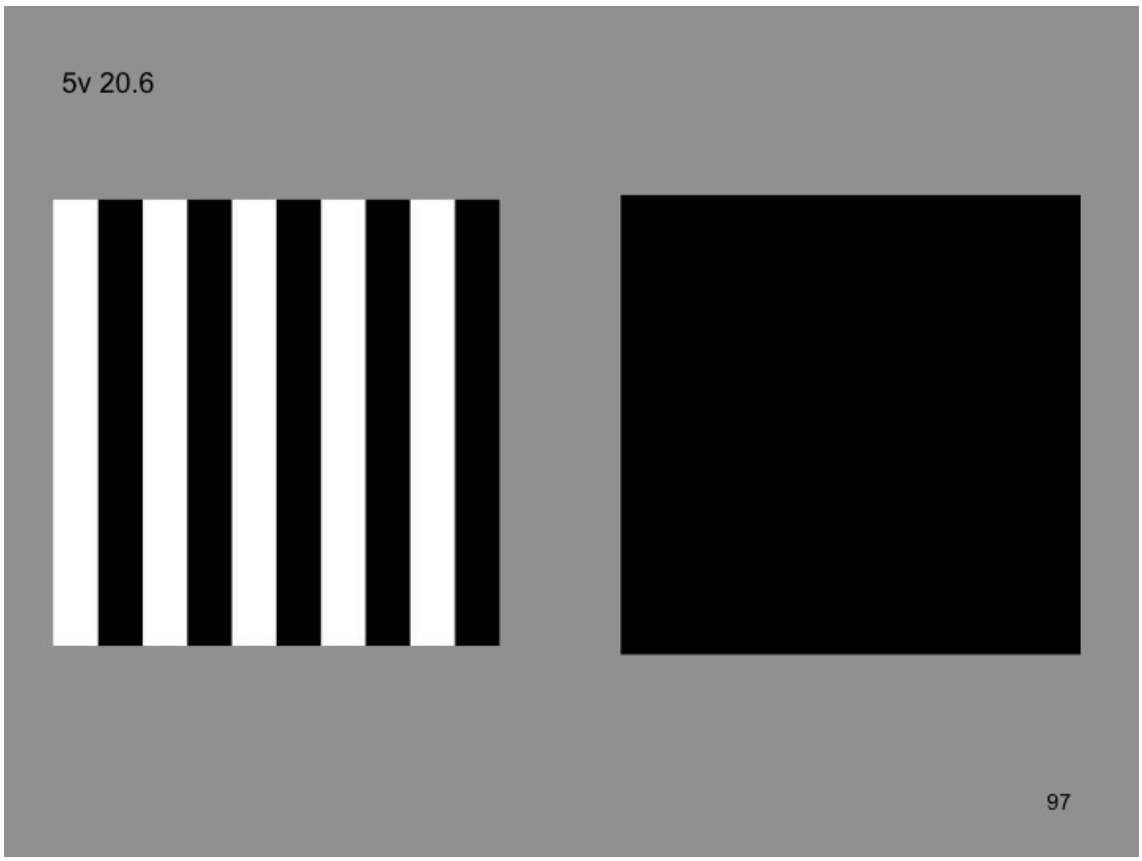
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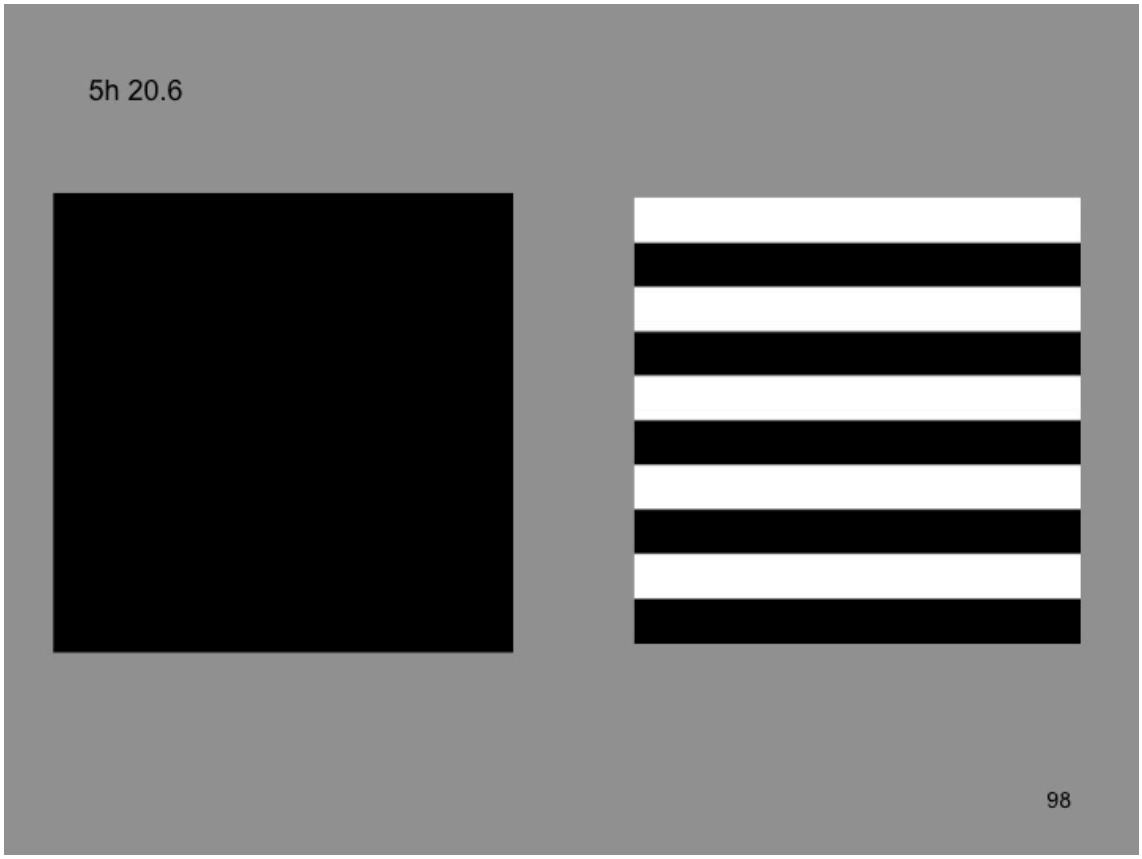
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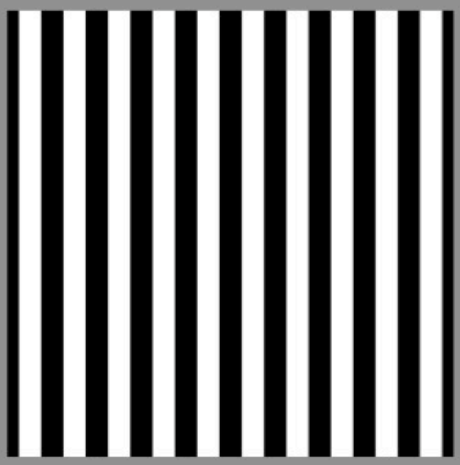

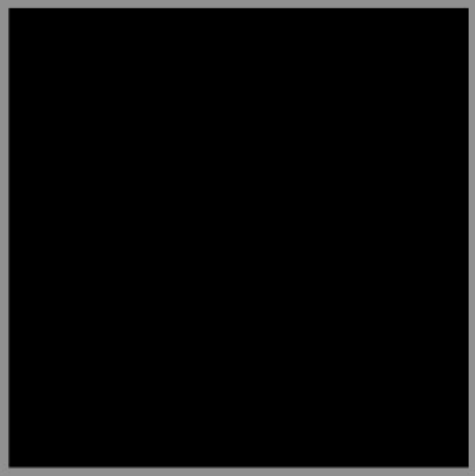

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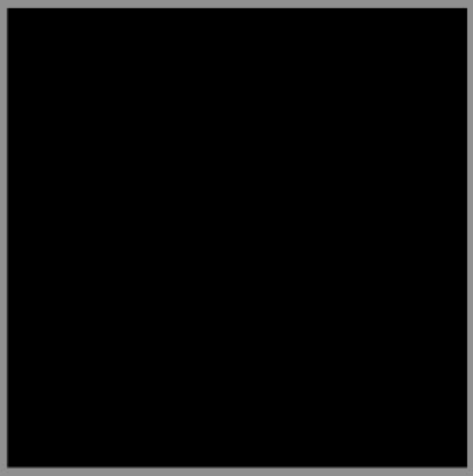

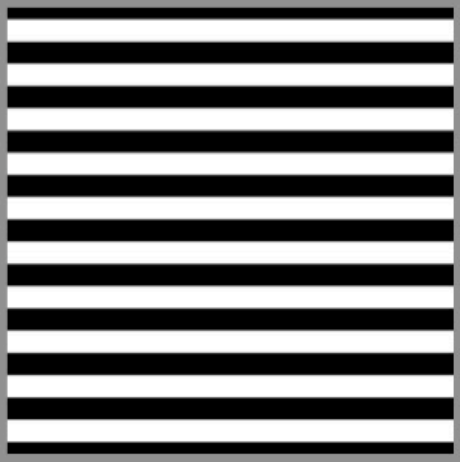

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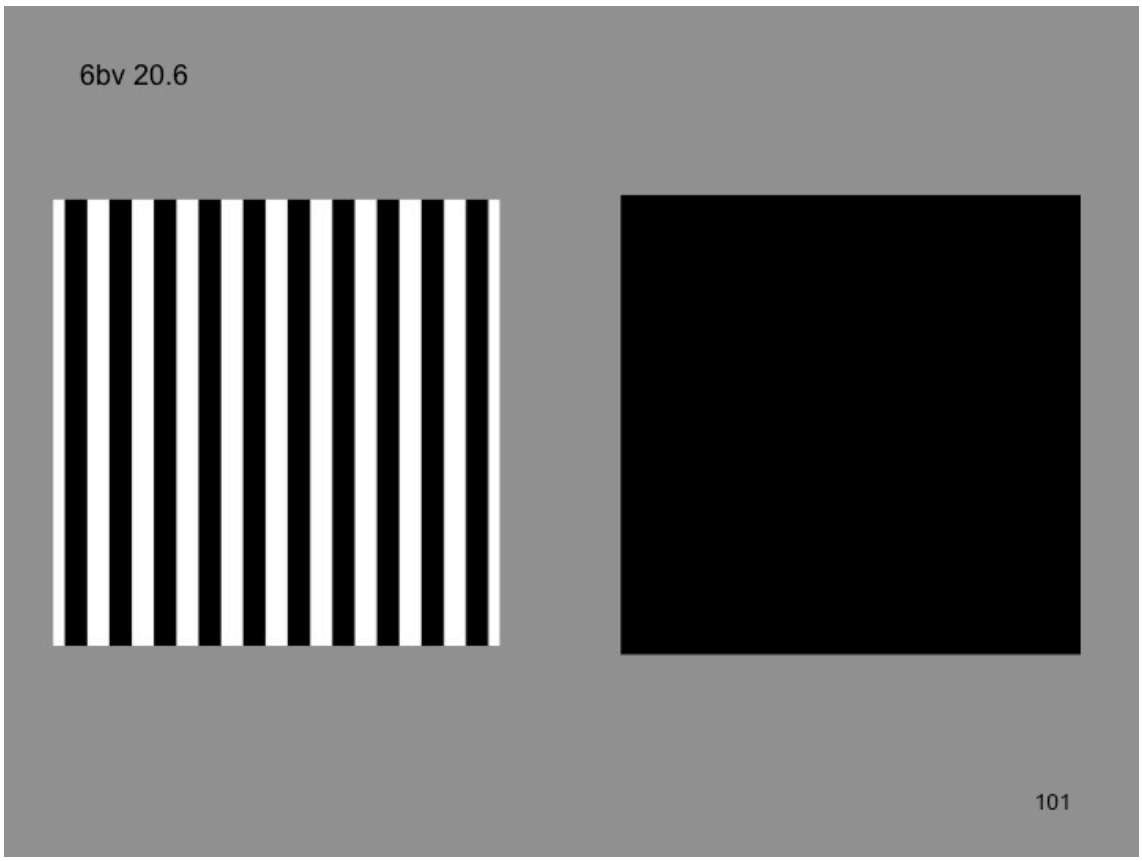
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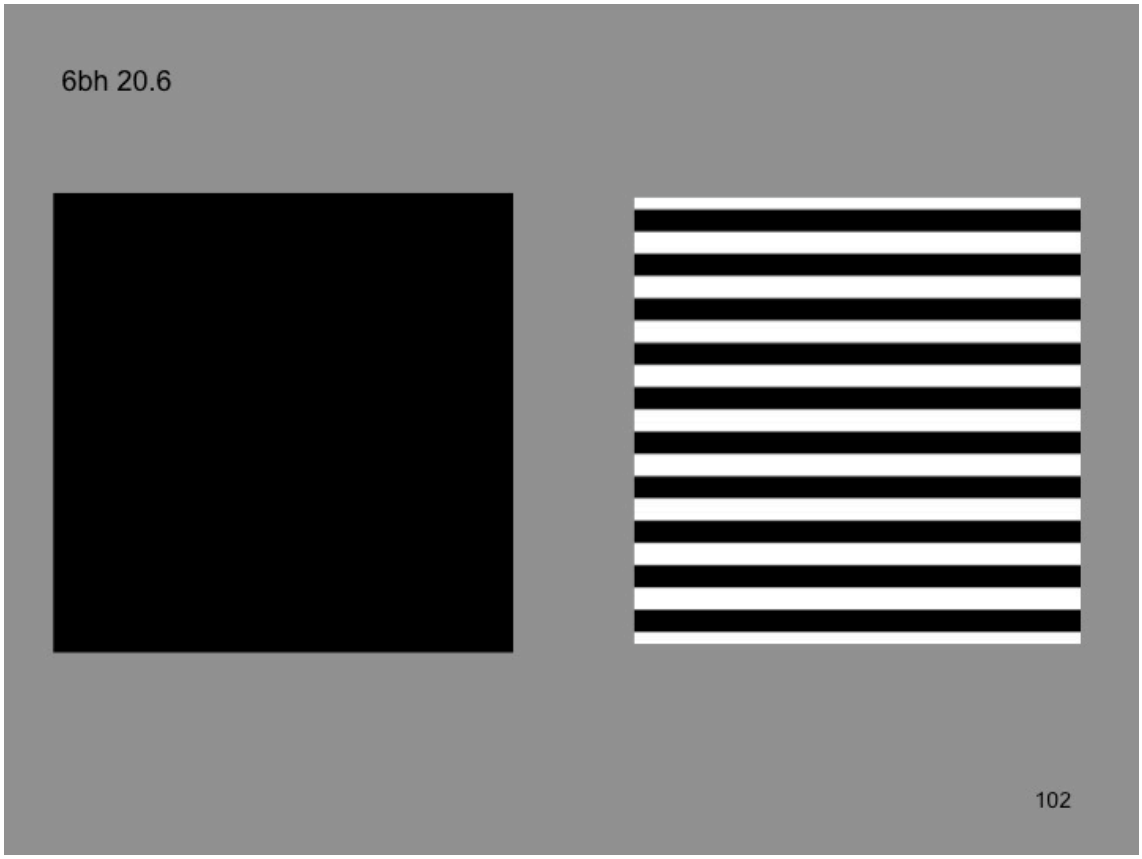
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